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FACULTY OF SOCIAL SCIENCES

Department of Social Statistics and Demography

Social determinants of nutritional outcomes in young children in Sri Lanka: Analysis of the 2016 Demographic and Health Survey

by

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Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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Sri Lanka has been able to achieve satisfactory progress in health and developmental goals, characterized by substantial declines in infant, child and maternal mortality rates. Despite low mortality levels, better access to healthcare, food security and economic growth, there is little improvement in child nutrition – a paradox and a critical policy challenge that remain unresolved for over the last two decades. Low Birth Weight (LBW), child stunting, wasting and underweight have remained high at constant levels for past 10 years, with increasing health inequalities across different social and ethnic groups. On the other hand, rapid socioeconomic and nutrition transitions can lead to the emergence of a *double burden of malnutrition* (DBM). This has not been systematically investigated at the national level. Using the data from most recent Sri Lankan Demographic and Health Survey (SDHS), this research investigates the bio-behavioural, socioeconomic and demographic factors underlying inequalities in child nutritional outcomes in Sri Lanka. Further, it examines the risk factors associated with the prevalence of DBM at the household level.

The first paper investigates social inequalities underlying LBW outcomes using fixed and random intercept logistic regression models and inequality measures. The results show that LBW is linked to socioeconomic disadvantage, as it is highly concentrated among poor households and in rural and the estate sector; in particular Indian Tamils in the estate sector have the highest risk of LBW of any comparable sub-group of the population. There was substantial unobserved variation in LBW outcomes between mothers. Regression models confirmed that LBW is more closely associated with maternal biological factors, including maternal depletion, than it is with socioeconomic factors.

The second paper examines the extent of inequalities in child stunting, wasting and underweight and how these are distributed across different socioeconomic groups, residential sectors and geographical regions. The results show that LBW and BMI are associated with all three outcomes. The effect of child immunisation and feeding practices was not strong for child undernutrition outcomes. Results also suggested that characteristics of the children, their mothers and the households in which they live explain most of the variance in child undernutrition. There is relatively little variation between communities that is not accounted by the composition of those communities.

The third paper assesses the driving factors associated with coexistence of child stunting and maternal overweight and obesity at the same household. The results confirm that Sri Lanka is facing a DBM at the household level, with the coexistence of child stunting and maternal overweight. LBW status, maternal age, number of household members, delivery mode, wealth status, ethnicity and province are significantly associated with DBM.

Overall, the survey evidence demonstrates that LBW and undernutrition among children are clearly interlinked with socioeconomic disadvantages. The findings of this study suggest that Sri Lanka is facing a dual nutrition challenge of reducing both child undernutrition and maternal overweight and obesity, which are intertwined. The study recommends that child health policies and interventions in Sri Lanka should address both under-nutrition as well as preventing obesity and obesity-related chronic disease risks of malnourished children and their mothers.

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Research Thesis: Declaration of Authorship

Print name: Gayathri Abeywickrama

Title of thesis: **Social determinants of nutritional outcomes in young children in Sri Lanka: Analysis of the 2016 Demographic and Health Survey**

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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Signature: Date:

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Definitions and Abbreviations

ANC .... Antenatal care

AIC....................................... Akaike information criterion

AOR .... Adjusted odds ratio

ARI... Acute respiratory infections (ARIs)

BIC.. Bayesian information criterion

BMI .... Body mass index

CI .... Concentration Index

Ci .... Confidence intervals

CC .... Concentration curve

DDS .... Dietary diversity score

DBM................................. Double burden of malnutrition

DHS .... Demographic and Health Survey

DOHadD .... Developmental Origins of Health and Disease

FAO .... Food and Agricultural Organization

HAZ .... Height-for-age Z-scores

LBW................................. Low birth weight

IFA .... Iron and Folic Acid

IYCF .... Infant and Young Child Feeding

LMICs .... Low- and middle-income countries

MDD .... Minimum dietary diversity

MDS.......................... Maternal Depletion Syndrome

MMF .... Minimum meal frequency

OECD .... Organization for Economic Cooperation and Development

OR .... Odds ratios

PCA .... Principal component analysis

PSU .... Primary sampling unit

SLDHS .... Sri Lanka's Demographic and Health Survey

SD .... Standard Deviation

SDG .... Sustainable Development Goal

SCOWT............................ Stunted child-overweight mother

SCOB............................... Stunted child-obese mother

SCUWT............................ Stunted child-underweight mother

SCNWT............................ Stunted child-normal weight mother

UN .... United Nations

UNDP……………………..United Nations Development Programme

UNICEF............................ United Nations Children's Fund

USAID .... United States Agency for International Development

WASH .... Water, Sanitation and Hygiene

WAZ .... Weight-for-age Z-scores

WHO .... World Health Organization

WHZ................................ Weight-for-height Z-scores

Chapter 1 Introduction

1.1 Introduction

Malnutrition, encompasses all forms of undernutrition (stunting, wasting being underweight), inadequate vitamins or minerals, overweight, obesity, and resulting diet-related non communicable diseases has remained a critical global health crisis in low- and middle-income countries (Development Initiatives, 2020). Millions of people suffer from various forms of malnutrition, for instance, approximately 151 million children who are aged under five years are stunted, 50.5 million children under-five are wasted, while 38.3 million children are overweight, 2.01 billion adults are either overweight or obese and 462 million are underweight (Development Initiatives, 2020; World Health Organization, 2018a).

Table 1.1 Definition of terms

Health inequality	Differences in health status or in the distribution of health determinants between different population groups.
Malnutrition	Malnutrition includes undernutrition (resulting in wasting, stunting and underweight), inadequate intake of vitamins or minerals, overweight, and obesity. It can result in diet-related non-communicable diseases.
Stunting	Children whose height-for-age *z*-scores are below minus two standard deviations (-2 SD) from the median of the WHO Child Growth Standards.
Wasting	Children whose weight-for-height *z*-score are below minus two standard deviations (-2 SD) from the median of the WHO Child Growth Standards.
Underweight	Children whose weight-for-age *z*-score are below minus two standard deviations (-2 SD) from the median of the WHO Child Growth Standards.
Low birth weight	Birth weight less than 2500 grams.
Overweight	Children whose weight-for-height *z*-score is more than 2.0 standard deviations above the mean on the WHO Child Growth Standards.
Maternal overweight and obesity	Mothers with a body mass index (BMI) of 25–29.9 are classified as overweight. Mothers with a BMI of 30 or greater are obese.
Double burden of malnutrition	The coexistence of undernutrition along with overweight and obesity, or diet-related non-communicable diseases, within individuals, households and populations, and across the life course.

The problem of malnutrition is associated with socioeconomic inequalities as health outcomes are not equally distributed throughout the globe. Disparities in malnutrition outcomes between more and less socially and economically advantaged groups are widely acknowledged in low- and middle-income countries (LMICs), as the outcomes differ by a range of social, cultural, economic, environmental, and healthcare factors (Arcaya et al., 2015; Van de Poel et al., 2008). Malnutrition among poor societies is illustrated as a "syndrome of development impairment" which refers to the physical and cognitive development of children (Martorell, 1999), as malnutrition influences individuals' growth, wellbeing and also their economic productivity at later ages (de Onis and Branca, 2016; Greffeuille et al., 2016; World Health Organization, 2014a). There have been some overall reductions in the global malnutrition rates, however, progress in combatting malnutrition in all its forms is unsatisfactory and the extent of the problem remains unacceptably high across regions such as sub-Saharan Africa and South Asia (Van de Poel et al., 2008). The nutrition targets in these countries are yet to be achieved. The double burden of malnutrition (DBM) or the coexistence of persistent undernutrition (stunting, wasting and underweight), together with over or bad nutrition (overweight and obesity) either at the individual, household or population level have become an emerging reality that is disproportionately affecting LMICs (Black and Sesikeran, 2018; Popkin et al., 2020). In these countries, DBM predominantly occurs in the form of child undernutrition and maternal overweight within the same household (Popkin et al., 2020). Rapid economic growth in parallel with globalization and urbanization leads to substantial changes in lifestyles, characterised by shifts in dietary patterns and physical activities. These are identified as a driving force of this simultaneous occurrence of child undernutrition and maternal overweight.

In recognition of the need to tackle contrasting and confounding forms of malnutrition, the United Nations (UN) General Assembly defined a set of nutritional targets that member countries need to achieve by the year 2030. The second of the Sustainable Development Goals (SDGs), particularly emphasises the need to eradicate all forms of malnutrition worldwide (United Nations, 2015b, 2017). The global nutrition targets, endorsed by the World Health Organization are the most comprehensive milestones to be achieved by the year 2025, with targets for maternal, infant and young child nutrition (MIYCN) indicators including low birth weight, stunting, wasting, underweight/overweight in children under five years of age; and anaemia, overweight and obesity in women of reproductive ages (Development Initiatives, 2020).

Despite the overall reductions in child undernutrition rates, South Asia still has the highest prevalence and burden of stunting and wasting among children aged under five years (Development Initiatives, 2020). Notwithstanding persistent undernutrition, the countries in South Asia are undergoing a nutrition transition accompanied by rapid economic growth. This is a particular concern for their health systems, which are confronted with the challenges of coping with increasing non-communicable diseases (NCDs) associated with overweight and obesity, whilst they are still discovering ways of tackling diseases associated with child undernutrition. However, less is known about this simultaneous burden of malnutrition in the South Asian context (Florentino, 2011; Hauqe et al., 2019).

The focus of this PhD research is to examine the unique case of Sri Lanka — an ethnically diverse post-conflict country in South Asia, where the rates of child undernutrition outcomes and adult overweight and obesity have remained high. This thesis seeks to contribute to a systematic understanding of socioeconomic inequalities in child low birth weight outcome, child nutritional outcomes and the potential double burden of malnutrition at the household level, using data from the first post-conflict nationwide Demographic and Health Survey conducted in 2016. The occurrence of both child undernutrition and overnutrition despite Sri Lanka's health achievements in other areas presents a puzzle in Sri Lanka, with little evidence, calling for an in-depth examination of determinants underlying malnutrition in Sri Lanka.

1.2 The research problem: paradoxical situation in Sri Lanka

Over the last three decades, Sri Lanka has made commendable progress in its health indicators. The country is often hailed as a model for the achievement of "good health at low cost" (Jayasinghe, 2010; John C. Caldwell, 1986; Rannan-Eliya and Sikurajapathy, 2008; Thresia, 2013). Sri Lanka is in the late-expanding phase of the demographic transition (Rannan-Eliya and Sikurajapathy, 2008), characterised by a steady decline in both fertility and mortality. The country has also reached the third stage of the epidemiological transition, showing a clear shift from infections to non-communicable diseases, with a reduction in mortality across all ages, accompanied by advancement in life expectancy (Abeykoon, 2000; De Silva et al., 2009; Dissanayake 2000; Perera, 2017).

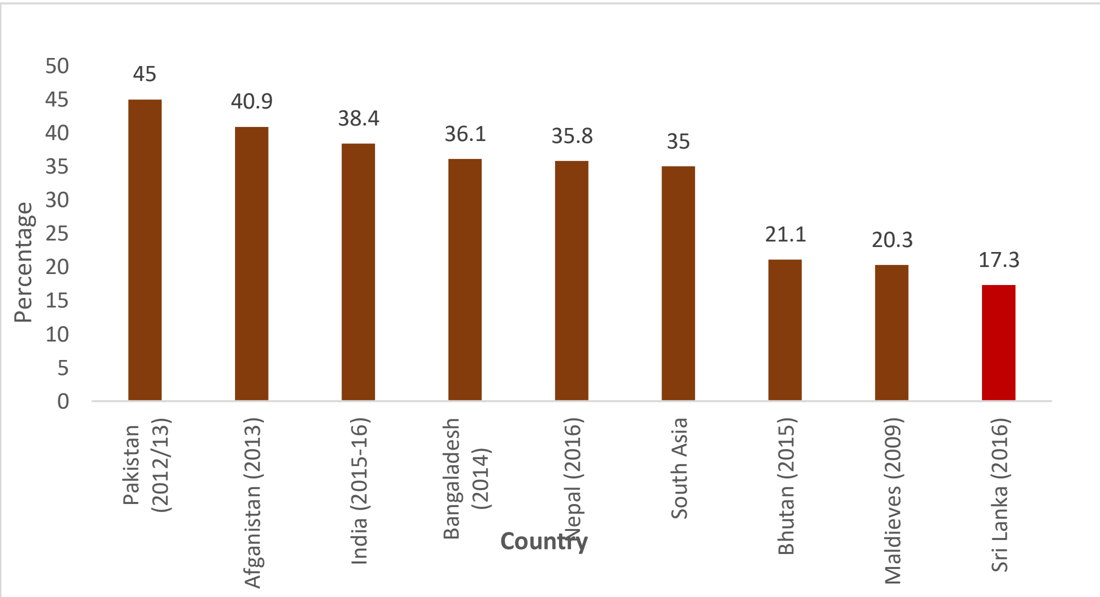
The overall life expectancy at birth in Sri Lanka in 2015 was estimated at 74.9 years, which is considerably higher than other South Asian countries (World Health Organization, 2015a). This was higher than in India and Bangladesh which recorded life expectancies of 68.3 and 71.8 respectively (Department of Census and Statistics, 2017; United Nations, 2015a). Infant mortality rates in Sri Lanka have also declined from 29 deaths per 1,000 live births in 1980 to as low as 8 per 1,000 by the end of 2015. The under-five mortality rate has also shown a steady decline from 13.7 (per 1,000 live births) in 2002 to 8.8 in 2017 (Ministry of Health Nutrition and Indigenous Medicine, 2015). Recent data show an estimated maternal mortality ratio of 32 deaths per 100,000 live births, less than two-thirds of that two decades ago and significantly less than the current levels in other South Asian countries (World Health Organization, 2014b, 2015a).

Apart from the achievements in child and maternal health outcomes, Sri Lanka provides a comprehensive range of health care services, with almost universal coverage for the services such as skilled public health workers including birth attendance, antenatal care, and DPT3 immunisation (World Health Organization, 2014b). The public health services are offered free of charge to all citizens, as they are prioritised under the national health policies and programmes.

Sri Lanka also has relatively low levels of child undernutrition compared with other South Asian countries (The World Bank, 2015a; World Health Organization, 2014b) (Figure 1.1). For example, Pakistan has the highest percentage of stunting in children under five in South Asia at 45 per cent along with Afghanistan and India around 40 per cent (UNICEF, 2017) (see Table 1.1 for a definition of "stunting"). With these achievements in health, Sri Lanka was able to reach the expected targets in achieving Millennium Development Goal (MDG) 5 on maternal and child health (United Nations, 2015a; World Health Organization, 2014b). Despite such improvements, MDG targets on nutrition were not sufficiently met. The unmet health concerns related to undernutrition have therefore emerged as an "unfinished agenda" that needs attention within the United Nations (UN) Sustainable Development Goals (World Health Organization, 2014b).

Table 1.2 shows that Sri Lanka has a relatively higher income per head and spends a larger proportion of its national income on health, than other selected LMICs who have similar gross national income (GNI). However, despite lower infant mortality rates, nutrition achievements in Sri Lanka are far less satisfactory which is characterised by higher proportions of child underweight and wasting than these countries.

Figure 1.1 Prevalence of stunting in South Asian countries



Source: UNICEF/WHO/World Bank Group Joint Child Malnutrition Estimates, 2017

Table 1.2 International comparisons of health and nutritional outcomes, expenditures, and current health expenditure per head, PPP

Country	GNI per capita (U$)	IMR (per 1000 live births)	Underweight (per cent)	Stunted (per cent)	Wasted (per cent)	Current health expenditure per capita, PPP (current international U$)
Sri Lanka	4,020	6	20.5	17.3	15.1	503.5
Indonesia	4,050	20	17.7	30.5	10.2	367.9
Philippines	3,850	22	19.1	30.3	5.6	371.7
Vietnam	2,540	16	13.4	23.8	5.8	375.6
Cameroon	1500	50	11	28.9	4.3	173.8
Ukraine	3370	7	4.1	22.9	8.2	584.5

*IMR = Infant mortality rate (per 1,000 live births)

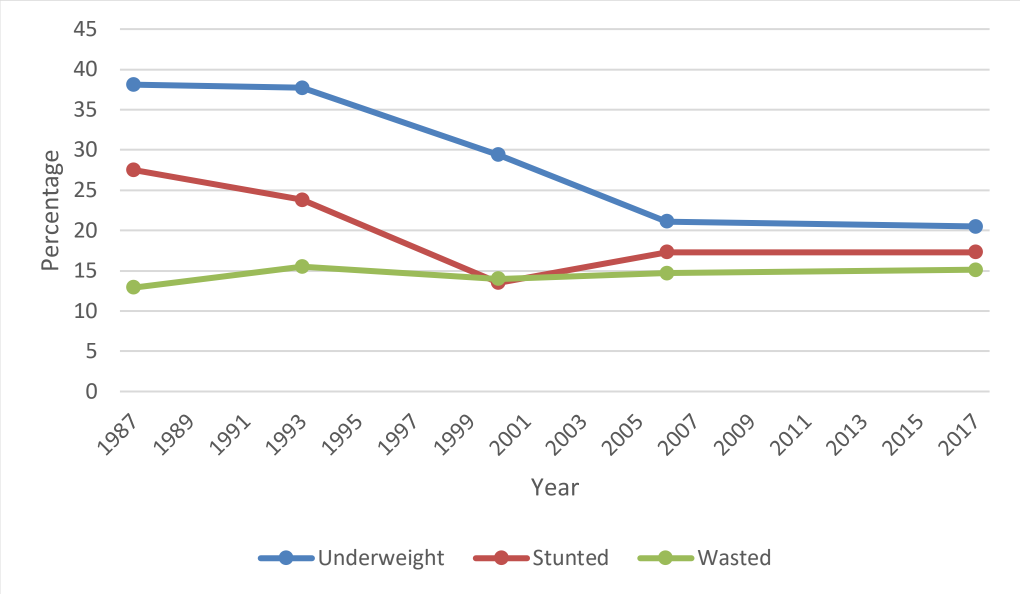
Source: The World Bank, accessed from https://www.worldbank.org/

Moreover, improvements in the levels of child stunting, wasting and underweight (see Table 1.1 for definitions of "wasting" and "underweight") in Sri Lanka have stalled or plateaued over the last decade (Department of Census and Statistics, 2017). Data from the 2016 Demographic and Health Survey (DHS) in Sri Lanka show that 17.3 per cent of children are stunted, 4 per cent are severely stunted, 15 per cent are wasted and 20.5 per cent are underweight. The level of stunting has remained high at 17.3 per cent between the year 2000 and 2016 and there has been little or no progress in wasting and underweight indicators (Figure 1.2).

Adding to the crisis of undernutrition, the percentage of babies born with low birth weight has also stagnated over the last two decades (2000-2016) at around 16-17 per cent, and the low birth rate has become a public health problem for the country (Anuranga et al., 2012; Ministry of Health Nutrition and Indigenous Medicine, 2015). Moreover, it has been consistently evident that the gains in child health and nutrition indicators have been unequal within and between certain social groups and geographic regions, with disadvantages being severe among poor wealth groups in the estate sector engaged in tea plantations and those exposed to civil war and conflict between 1980 and 2010 (Jayawardena, 2014, 2020; World Health Organization, 2014b).

Despite numerous health gains including extensive, free maternal and child health services, poor performance in child undernutrition outcomes exist in Sri Lanka. It is rather paradoxical that child undernutrition outcomes have shown little progress for nearly two decades, with considerable disparities among population subgroups.

Figure 1.2 Trends in the nutritional status of children under the age of 5 years in Sri Lanka

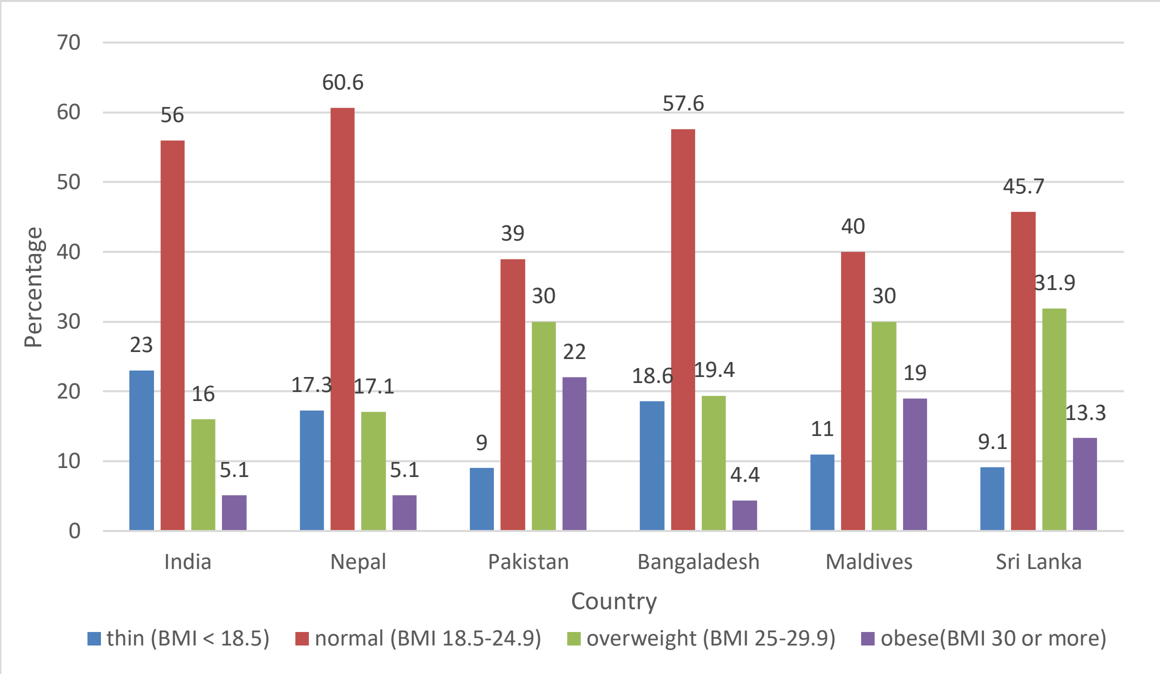


Source: Department of Census and Statistics, 2017.

Despite the hampered progress in child undernutrition, rising overweight and obesity among both women and children have emerged as major health concerns revealing a double burden of malnutrition in Sri Lanka. For example, 5.1 per cent of children aged under five years are reported as overweight or obese, while for the women, 32 per cent are reported as overweight while 13 per cent are obese (Black and Sesikeran, 2018; Department of Census and Statistics, 2017; Institute of Poverty Analysis, 2018). Figure 1.3 illustrates the distribution of women's body mass index (BMI) among selected Asian countries. India shows the lowest prevalence of overweight (16 per cent), while Sri Lanka recorded almost 32 per cent as the highest recorded figure for overweight. Women obesity rates were highest in Pakistan (22 per cent), and 13.3 per cent in Sri Lanka.

At the same time, Sri Lanka, as a middle-income country going through enormous demographic and epidemiological changes, with an accelerated increase in the proportion of the population of older people aged 6- and above and alongside a rise in the proportion of the population with NCDs. The rapid increase of NCDs has become a serious public health and economic concern in Sri Lanka; NCDs are estimated to contribute to 83 per cent of total deaths while cardiovascular diseases (34 per cent), stroke and diabetes become mainstream among total deaths (World Health Organization, 2018c).

Figure 1.3 Distribution of body mass index of women in reproductive ages among the selected South Asian countries



Source: Author's own analysis based on recent Demographic and health survey data

In the light of Sri Lanka's unsatisfactory progress in child nutritional outcomes, combined with the emergence of the double burden of malnutrition, the motivation behind this research is to understand the socioeconomic and demographic factors associated with child undernutrition and the double burden of malnutrition, and in particular the socioeconomic inequalities in these outcomes. The lack of progress in combatting malnutrition, despite successful health achievements in other areas makes Sri Lanka an interesting case to investigate. By studying the case of Sri Lanka, the thesis hopes to contribute to a better understanding of the malnutrition problem and to identify policies and strategies that might reduce child undernutrition and the double burden of malnutrition in the country.

1.3 Demographic and health care profile of Sri Lanka

This section addresses the geographic, demographic and socioeconomic characteristics of Sri Lanka. Later, it briefly discusses the country's health profile and current health challenges.

1.3.1 Geographic, demographic, socioeconomic and health profile of Sri Lanka

Sri Lanka is an island located in the Indian Ocean. It is well known as a pearl of the Indian Ocean covering a total area of 65,610 square kilometres with 21.67 million inhabitants in 2018 and a population density of 325 persons per square kilometer. The average annual population growth rate shows a declining trend of 0.7 per cent per year compared to the previous population growth rate of 1.2 per cent per year in 2001 (Department of Census & Statistics, 2012).

Sri Lanka is a multi-ethnic, multi-religious country with a population which is predominantly Sinhalese (constituting around 75 per cent). Of the remainder, 11.1 per cent are Sri Lankan Tamils, while 9.3 per cent are Moors[1]. There are also Indian Tamils comprising 4.1 per cent of the population. The Indian Tamils, who are highly involved in the tea plantation sector (called the "estate" residential sector) were brought to Sri Lanka by the British in the nineteenth century to work on tea and rubber plantations and they remain settled in the "tea country" of south-central Sri Lanka. In addition, there are other small minority groups, such as Malays and Burghers, who descend from European colonies, and who are often described simply as "others" in population census and surveys (Department of Census & Statistics, 2012).

The first level administrative system in Sri Lanka is the provinces. The country is divided into nine provinces, which are in turn divided into districts (the second-level administrative division within the provinces). There are 25 districts dispersed among these provinces as shown in the map of Sri Lanka (Figure 1.4). Districts are further subdivided into municipalities and, for administrative purposes, each municipality is divided into wards and wards into Grama Niladhari divisions (sub-wards) (Department of Census & Statistics, 2012).

There are three main residential sectors: urban, rural and estate. The urban sector (18.4 per cent of the population) is comprised of areas administered by municipal and urban councils; the estate sector (4.4 per cent) is predominantly concentrated in the tea plantation areas, while the rural sector (77.4 per cent) comprises the areas that are not captured by the urban and estate sectors. The North Central province is mostly rural (96.0 per cent) while the Central and Sabaragamuwa provinces have the highest estate sector population (Department of Census & Statistics, 2012). The aforementioned Indian Tamils are settled in the estate sector and predominantly work in the tea plantations. In general, they are considered aa a "disadvantaged group" because of low socioeconomic conditions compared to other population groups (Ahamed, 2014).

Sri Lanka is recently upgraded as an upper-middle-income country with per capita gross domestic product (GDP) of USD 4,102 in 2019 (The World Bank, 2019). The national poverty headcount ratio declined from 15.3 per cent in 2006 to 4.1 per cent in 2016, although heterogeneity of poverty level remains with wide differences between sectors. The most affected sectors in poverty are the estate

[1] Sri Lanka moors/Ceylon moors/Lanka Yonaka, colloquially referred to as Muslims who are predominantly followers of Islam. They are mainly native speakers of the Tamil language with the influence of Sinhalese and Arabic words

sector followed by the rural sector (World Health Organization, 2017b). Sri Lanka's Human Development Index (HDI) value for 2018 is 0.780, classified under the high human development category (UNDP, 2019). The economy has recently shifted towards the service sector, with enhanced performance in industry and a slight decline in agricultural activities (Ahamed, 2014; Central Bank of Sri Lanka, 2019).

Sri Lanka has almost completed the demographic transition with low mortality rates and fertility rates approaching replacement levels (Caldwell, 1996). It underwent a significant fertility transition (Abeykoon, 2000; Yapa and Siddhisena, 1998) during the 1960's and it is going towards the last stage of the demographic transition (Dissanayake, 1996; The World Bank, 2013). The drop in fertility took place alongside many other developments such as economic growth, increasing levels of education, female empowerment, provision and acceptance of family planning services (Abeykoon, 2000; De Silva et al., 2009; De Silva et al., 2010; Dissanayake, 1996; Perera, 2017).

Mortality in Sri Lanka has also declined significantly during the second part of the twentieth century and it is now experiencing a very low crude death rate of about 6.5 per 1,000 population (United Nations, 2019). Driven by a significant reduction of mortality levels, life expectancy at birth in Sri Lanka has also increased by almost 20 years from 57.6 years in 1960 to 74.9 years in 2015 (Department of Census and Statistics, 2017). At the population level, female life expectancy improved steadily from 71.7 years in 1980-1985 to 78.9 years in 2010-2015 whereas the corresponding increase for males was from 66.8 years to 71.2 years for the same period (Amarasinghe et al., 2015; United Nations, 2015a).

Figure 1.4 Administrative province and district map of Sri Lanka

Source: Department of Census and Statistics, 2017

The health sector in Sri Lanka has performed noticeably well in terms of achieving low levels of maternal and child mortality with high immunisation coverage (UNDP, 2014; World Health Organization, 2007, 2014b). Sri Lanka became the first country in the less developed South-East Asian region to provide universal health care and free education to its people (World Health Organization, 2014b, p. 49). Sri Lanka adopted a "free health policy" in 1951 after gaining independence and ever since it has continued to provide free health care for its population (United Nations, 2016). The health system is known for providing high volumes of service delivery at relatively low cost and is hence known as an example of "good health at low cost" model (Jayasinghe, 2010; Rannan-Eliya and Sikurajapathy, 2008; Thresia, 2013).

In Sri Lanka, both the public and private sectors provide health care. However, provision is mainly in the public sector, which provides health care for nearly 60 per cent of the population encompassing the entire range of preventive, curative, and rehabilitative health care provision (Jayasekara and Schultz, 2007). Private institutions and health providers also play a vital role in the health care sector of Sri Lanka, complementing the activities of government health care institutions (Rannan-Eliya et al., 2015; Tharanga et al., 2018). The private sector mainly provides outpatient care, drugs and lab examinations. Medical professionals who practise in public health sector often provide private practices after public health service hours. Patients in the lowest wealth groups often seek private outpatient services due to the constraints in public health services such as long queues and waiting hours, etc. It is estimated that, in the year 2018, the private sector contributed 50 per cent of total health expenditure in Sri Lanka (Higashi et al., 2020).

The country managed to perform well in reaching the UN MDGs, halving poverty and showing improvements in the areas of maternal and child health as well in educational attainment. Despite having achieved favourable health indicators at "good health at low cost", particularly in maternal and child health, issues remain, such as child undernutrition which is identified as unfinished agenda, and has not shown any improvements since the beginning of the last decade (Higashi et al., 2020; World Health Organization, 2014b). Also, due to the increase of life expectancy and population ageing, Sri Lanka today faces new challenges in addressing non-communicable and degenerative diseases in adults such as heart disease, cardiovascular disease, and diabetes which are becoming more common (The World Bank, 2015a; World Health Organization, 2014b, 2015a).

1.4 Aims, research questions, hypotheses and objectives

The aim of this PhD research is to examine the extent of inequalities in childbirth weight and child nutritional outcomes and investigate the double burden of malnutrition at the household level, based on a paradoxical situation in Sri Lanka – marginal improvements in child health and undernutrition outcomes alongside satisfactory achievements in other areas of health care practices.

The thesis particularly aims to investigate how bio-behavioural, socioeconomic and demographic factors are associated with low birth weight and children's undernutrition outcomes in Sri Lanka and how these factors account for socioeconomic inequalities in such outcomes. This research will further examine what factors are associated with the coexistence of child stunting and maternal overweight and obesity within the same household. The analysis sheds light on key indicators of malnutrition from birth through infancy, early childhood and adulthood. These include low birth weight (LBW), stunting, wasting, underweight, maternal overweight and obesity. Exploring key factors and their underlying inequalities, provide a better understanding of the persistent undernutrition problem and the emergence of the double burden of malnutrition in an underexplored context of Sri Lanka. With the use of data from a recent nationally representative Demography and Health Survey, conducted in 2016, this research uses a quantitative approach for three inter-related chapters presented in a research paper format. The first paper investigates social inequalities underlying LBW outcomes in Sri Lanka, the second paper examines the factors associated with child undernutrition outcomes and further examines how these factors account for socioeconomic inequalities in child undernutrition outcomes, while the third paper investigates what factors are associated with the double burden of malnutrition, more specifically the existence of stunted child/overweight or obese mother pairs within the same household in Sri Lanka. The detailed objectives and research questions pertaining to the three interrelated papers presented in this thesis are listed below.

Paper 1: Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and Health Survey 2016

Despite the marked reductions in infant child mortality rates, the proportion of babies with low birth weights (LBWs) in Sri Lanka has stalled at around 17 per cent over a decade, resulting in a critical public health problem in Sri Lanka, with a long-term impact on health outcomes, the disease burden and economic productivity. Despite taking numerous measures to improve child and maternal nutrition, the improvements in LBW outcome have been marginal. Existing studies of LBW are mainly restricted to small samples conducted in specific settings, hence further investigation on low birth weight in a broader spectrum using a nationally representative survey is needed. The main objective of this paper is to investigate the socioeconomic inequalities underlying LBW outcomes in Sri Lanka among socioeconomic groups, and across residential sectors using data from the Demographic and Health Survey conducted in 2016. We hypothesise that LBW is associated with socioeconomic disadvantage. Children born in poor households and to the Indian Tamil tea plantation workers in the estate sector are more vulnerable to LBW outcomes than their counterparts living in richer households in other rural and urban areas.

This paper addresses the following questions:

1. How is the low birth weight distributed among different socioeconomic groups and across residential sectors and geographical provinces?
2. What is the nature of the association between maternal nutrition depletion factors and low birth weight?
3. What are the socioeconomic inequalities in low birth weight outcomes by different residential sectors?

4. What are the maternal, socioeconomic and geographic factors associated with low birth weight at the maternal, household and community levels?

Investigating inequalities in LBW and risk factors by different subpopulation groups is crucial to understanding socioeconomic disadvantage in birth outcomes. Moreover, this analysis can highlight the interlinkages between maternal nutrition and childbirth outcomes and further disentangle the reasons why low birth weight rates have been stagnating for over a decade Finally, it sheds lights on the factors that could contribute to the development of policies and interventions to reduce the overall burden of LBW.

Paper 2: Understanding inequalities in child undernutrition outcomes in Sri Lanka

There is a lack of a consistent improvement in nutrition indices in Sri Lanka, for example, child stunting, wasting and underweight rates are reported as 17 per cent, 15 per cent and 21 per cent respectively, and these have remained at almost same level, over the last decade (2000-2016) (Department of Census and Statistics, 2017). In addition, it is evident that there are wide variations between different social and economic groups for these nutritional outcomes. Child chronic undernutrition is the highest among the Indian Tamil population group who live in the estate sector, demonstrating inequality in child undernutrition (Jayawardena, 2014; Rannan-Eliya et al., 2013). Sri Lanka was unable to attain the Millennium Development Goals (MDGs) targets for nutrition by 2015, and nutrition remains a public health challenge to policymakers in the country (World Health Organization, 2014b).

Existing studies of child undernutrition outcomes often do not distinguish socioeconomic inequalities in undernutrition outcomes or what determinants are major contributors to such inequalities. Alternatively, they focus solely on child undernutrition in specific settings. The main objective of this analysis is to examine the bio-demographic, socioeconomic and geographic factors associated with undernutrition in children under five years, and further, examine how these factors account for socioeconomic inequalities in child undernutrition in Sri Lanka. There is also a need to disentangle community effects on child undernutrition outcomes and explore the association between child feeding practices, child immunisation and child undernutrition

In this study, we further hypothesise that children in poor households and born to Indian Tamil mothers in the estate sector have a higher risk of stunting than their counterparts in other sectors.

This paper addresses the following questions:

1. What are the determinants of child undernutrition outcomes in Sri Lanka and the contributors to the extent of inequalities in child undernutrition by socioeconomic group, residential sector and geographical region?
2. What is the nature of the association between low birth weight and undernutrition outcomes?
3. What is the nature of the association between child immunisation and child nutritional status?
4. What is the nature of the association between infant and young child feeding practices (IYCF) and child nutritional status?
5. What are the maternal, socioeconomic and geographic factors associated with child undernutrition at the maternal, household and community levels?

Moreover, disentangling community effects on child undernutrition outcomes, exploring the association between child feeding practices and child immunisation and child undernutrition outcomes can offer useful insights on the likely success of policy intervention at broad scales to deal with the persistent undernutrition problem in Sri Lanka. This analysis can provide insights on how low birth weight and child undernutrition relate to each other, to further understanding the intergenerational cycle of malnutrition in Sri Lanka.

Paper 3: The double burden of malnutrition: the coexistence of stunted children and overweight and obese mothers in Sri Lanka

The high and persistent child undernutrition rates, together with rapidly rising rates of maternal overweight, obesity and non-communicable diseases have emerged as a public health challenge in Sri Lanka, which is linked with its rapid socioeconomic transition since the year 2,000 (Athukorala et al., 2010). This phenomenon is identified as a double burden of malnutrition (DBM) in LMICs, predominantly occurring in the form of the coexistence of child stunting and maternal overweight within the same household. There has been very little discussion, in the South Asian context, on the DBM at the household level, in contrast to the marked attention given to Latin American countries (Hossain et al., 2020; Popkin et al., 2020).

Compared to other LMICs including South Asian countries, achievements in health indicators are exemplary in Sri Lanka along with the highest economic performances. However, the increasing public health burdens of child undernutrition rates and maternal overweight are mainly being addressed as separate public health issues. In these circumstances, it is essential to understand that undernutrition and overnutrition are interconnected and occur simultaneously and that concerted policy actions should be put into place to tackle the DBM. On the other hand, the lack of nationally representative data on DBM at the household level has limited the systematic investigation of the DBM at this level in Sri Lanka. The main objective of this paper to examine how individual, maternal, household and residential factors are associated with the DBM, complementing the findings of the first two papers.

Specifically, this paper tries to answer the following questions:

1. What are the risk factors associated with child stunting status, and mother's overweight and obesity within the same household?
2. What are the factors associated with maternal overweight and obesity?
3. What is the nature of association between child and maternal dietary patterns and the prevalence of DBM?

This study further sheds light on the common predictors for the coexistence of stunted child/overweight or obese mother pairs and other forms of the DBM at the household level, how these predictors are distributed among different population subgroups, what this reveals about the dietary patterns of both children and mothers, and how these dietary patterns relate to the DBM at the household level. The results of the analysis can offer crucial inputs for policymakers who are concerned that nutrition-oriented prevention programmes should take holistic approaches to tackle the DBM at the household level.

1.5 Author's contribution

I conceptualised the proposal for this thesis including the objectives, research questions, research hypotheses and relevant data sources. I obtained permission to access the DHS dataset from the Department of Census and Statistics in Sri Lanka. Since the DHS data in Sri Lanka are not in the public domain, ethical formalities need to be completed to access the datasets. Prior to analysing the DHS dataset, formal ethical approval was obtained from the University of Southampton *Ethics and Research Governance Online* (ERGO). Data were received in CVS format, which I imported first into EXCEL delimited output, and then later in DTA STATA format. I undertook data cleaning and selected appropriate variables for the analyses, merging data sets from the individual dataset and recode variables and creating composite indicators where necessary. To compute child growth measurements, WHO growth standards were undertaken and relevant statistical software such as SPSS (21.0), STATA (15.0) were used. In addition, ArcGIS (10.6) was used to generate relevant maps. Survey attrition was checked, and I had to decide the most appropriate way to use for this analysis. I was responsible for conceptualising and writing up each of the papers included in this thesis, and I attended relevant training courses in order to improve my knowledge on analytical methods. I am fully responsible for the analysis and interpretation of the data and the conclusions drawn.

1.6 Thesis structure

The remainder of this document is organized into seven chapters, based on a three-paper thesis format.

Chapter 2 provides a review of relevant literature related to global and regional child nutritional levels, trends and inequalities. Thereafter, it discusses the existing literature in Sri Lanka on child nutrition, more specifically on child stunting, wasting and underweight. Further, it presents the conceptual framework of the study by reviewing the existing frameworks. Factors integral to the conceptual framework are reviewed in the latter part of this chapter.

Chapter 3 describes the methodology applied in this study. It presents an overview of Demographic and Health Survey (DHS) data and highlights the difference between the standard DHSs and Sri Lanka's DHS. The chapter then describes the sampling design and the dependent and independent variables used in the study. It further adds the concepts and measures of health inequalities. Subsequently, it describes the main analytical methods used in each chapter.

Chapter 4 presents the first analysis: "Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and Health Survey 2016". A condensed version of this chapter was published in *BMJ Open 10(5)* (Abeywickrama, Padmadas and Hinde, 2020) (Appendix A). Before publication, this paper was also presented at the annual conference of the British Society for Population Studies (BSPS) at the University of Cardiff.

Chapter 5 includes the second paper on "Understanding inequalities in child undernutrition outcomes in Sri Lanka". The results from this chapter relating to child stunting were selected for a presentation at the European Population Conference, Padova, 2020 (the conference was cancelled due to COVID 19). Part of the findings of this Chapter are included in a journal article which is currently under review with the British Journal of Nutrition.

Chapter 6 consists of the third paper: "The double burden of malnutrition: the coexistence of stunted children and overweight and obese mothers in households Sri Lanka". This paper is intended for submission to an international journal by January 2021.

Chapter 7 Discusses the findings and lists recommendations for policy and further research.

Chapter 2 Literature review

2.1 Introduction

This chapter synthesises evidence from previous studies on the existence, magnitude and trends in child undernutrition at the global and regional level with a special focus on Sri Lankan studies. It also presents the recent evidence for the emerging double burden of malnutrition at the global level. Through conducting a thorough review of existing evidence, it aims to highlight the gaps in research and to provide justification for the significance of this PhD. Firstly, it summarises the concepts and measures of child nutrition, then it synthesises the evidence on the existence and emergence of child undernutrition at the global and regional level and then in Sri Lanka. Empirical findings on the socioeconomic gradients are also identified and the limitations of current studies are outlined. This chapter reviews two existing conceptual frameworks proposed by Mosley and Chen (1984) and UNICEF (2013), then presents the conceptual framework of this study. The final section describes the child, maternal, household and geographic determinants of child undernutrition based on the conceptual framework of the study.

The literature review was carried out using various search engines including PubMed, Web of Science, Journal webpages, Google Scholar for official publications and reports produced by international organizations. The literature review also included books and reports on specific child nutrition-related topics. The following keywords and search terms were used; low birth weight; developing countries; Asia, undernutrition; children, causes of stunting, wasting and underweight among age under 5 children in developing countries; conceptual framework for child health/ nutrition, infant and young feeding practices; child growth; child/maternal anthropometric indicators; maternal BMI, double burden of malnutrition; household; stunted child, overweight mother pairs. Also, synonyms were used to verify that all publications with different definitions of words and phrases were included. For example, for the sub-heading 'Double burden of malnutrition, the following keywords were used: coexistence of malnutrition, simultaneous undernutrition and overnutrition. In order to allow for different combinations of search terms, Boolean operators were also used to refine the search. The literature search was included articles published from 1990 onwards (except a publication was considered significant to the study). All literature search results were stored and saved in the Endnote reference management software under subheadings, using APA referencing style.

2.2 Anthropometric/nutritional indicators to assess the nutritional status of children and mother

Anthropometric measures are a set of quantitative measures that are widely used as a tool to assess the nutritional status in children and women (Casadei and Kiel, 2020). These most common anthropometric measures are height-for-age, weight-for-age and weight-for-height for children and body mass index (BMI) expressed as percentiles or *z*-scores, representing the overall nutritional status of children and women (Gorstein et al., 1994; World Health Organization, 2006). In the present study, weight-for-age, weight-for-height and height-for-age *z*-scores calculated using 2006 WHO (World Health Organization) growth standards to measure the child undernutrition. WHO child growth standards are constructed based on an international sample of ethnically, culturally and genetically diverse, healthy children living under optimum conditions that are conducive to achieving a child's full genetic growth potential (World Health Organization, 2006). WHO growth standards replaced and addressed the limitations of the 1977 National Centre for Health Statistics (NCHS) and 2000 Centre for Disease Control (CDC) growth references. The WHO growth standards were constructed by the Multi-Centre Growth Reference Study conducted between 1997 and 2003 based on data from 8,500 children from Brazil, Ghana, India, Norway, Oman and USA representing widely different ethnic backgrounds and cultural settings (World Health Organization, 2006).

Some studies have found the application of the 2006 WHO growth standards to have implications for growth assessments when analysing trends of undernutrition over time (de Onis et al., 2006; Norris et al., 2009). For instance, a study carried out to compare the implementation of the WHO growth standards and NCHS standards using a pooled dataset of infants from Bangladesh, Dominican Republic, North America and Northern Europe found that infants who were healthily breastfed appeared to falter from two months onwards according to the NCHS reference. However, when they based their analysis on the WHO child growth standards, underweight rates were increased during the first six months and thereafter, it showed a decreasing trend. Similar trends could be seen for stunting, wasting and severe wasting, which were high for all ages during the first half of infancy according to the WHO growth standards compared to the NCHS reference (de Onis et al., 2006). Some studies in Sri Lanka also reflected the appropriateness of using the WHO Multi-Centre Growth Reference Study (MGRS) to assess the growth parameters of babies (Abeyagunawardena *et al*., 2018; Perera *et al*., 2014). A study conducted with 2,215 children from both sexes found that the weight and length of both male and female children significantly deviated from the WHO standard reference (Perera *et al*., 2014). However, none of the studies has compared child anthropometric measures with WHO growth estimates.

2.2.1 Stunting

Stunting or a low height-for-age (HAZ), reflects longer-term malnutrition, which is also termed as linear growth faltering or impaired growth in the first 1,000 days from conception until the age of close to three years, during which time the impaired growth has adverse functional repercussions for the child (Black *et al*., 2013; de Onis and Branca, 2016; UNICEF *et al*., 2017). Linear growth in early childhood is a well-established risk marker of healthy growth, failure to achieve this has an association with morbidity and mortality risk, poor cognition development and educational performances and an increased risk of chronic disease in later life. Stunting is also adopted as a key measure for child malnutrition in the SDG 2 of the UN 2030 Agenda for Sustainable Development (United Nations, 2017).

Some of the other long-term implications linked with stunting are reduced cognitive and neurological developmental function, weakened immune system which, if widespread in a population, may reduce the productive capacity at a national level (Black *et al*., 2008; Victora *et al*., 2008) The relationship between linear growth faltering in early life and an inter-generational cycle of malnutrition is well established. Short maternal stature can lead to restricted growth *in utero*, and a higher risk of low birth weight babies, who are potentially undernourished. Thus the cycle continues (Georgiadis and Penny, 2017).

In 2018, it was estimated that, globally, 149 million children are stunted. Due to the increased attention on malnutrition, the global prevalence of stunting decreased from an estimated 40 per cent in 1990 to 25 per cent in 2013. If this downward trend continues, the global number of stunted children will further decrease to 142 million in 2020 (de Onis and Branca, 2016). However, this assessment is not true for all regions with significant variations still existing between countries and regions (International Food Policy Research Institute, 2016). For instance, Asia and Africa still bear the greatest share of all forms of malnutrition at 55 per cent and 39 per cent respectively, when considered from the overall prevalence of stunting around the globe (Development Initiatives, 2020). Despite some improvement over the past decade, the level of child undernutrition remains unsatisfactory in Asian countries (Van de Poel *et al*., 2008; World Health Organization, 2015b). The highest levels of stunting are found in the South-Asia region, particularly in India, Pakistan, Bangladesh and Nepal. Studies in these countries often report inequalities in child health and nutritional outcomes, which are directly linked to the socioeconomic and demographic characteristics of a population (Akhtar, 2016; Mohammad *et al*., 2016; Thakur *et al*., 2011).

2.2.2 Wasting

Wasting or low weight-for-height is identified as an acute condition due to its relatively rapid emergence compared to other forms of malnutrition, such as stunting. It is considered to be a life-threatening result of poor nutrient intake and/or disease (International Food Policy Research Institute, 2016). It has been proven that children who are wasted have weak immunity and are vulnerable to long term growth delays and increased risk of death. Wasting has been reported to have the highest short-term case fatality rate among all forms of malnutrition, particularly when it is combined with stunting (Frison *et al*., 2020). Wasted children are at an elevated risk of life-threatening infections and even of death as a consequence of secondary immuno-deficiencies (inability of the immune system to fight infectious disease) and wasting could recur among surviving children, who could be potentially stunted or have other forms of longer-term disabilities (Harding et al., 2018). In 2018, approximately 49 million children aged under five were reported to be wasted, with 14 million severely wasted (International Food Policy Research Institute, 2016).Among these children, more than 15 per cent (27.6 million children in 2016) are to be found in South Asian countries such as India and Sri Lanka, which have recently observed rising prevalence rates (Harding *et al*., 2018).

2.2.3 Underweight

Child underweight is represented as low weight-for-age. Child underweight is identified as a composite measure which is influenced by both acute (wasting) and chronic (stunting) undernutrition, but without any distinction between them (World Health Organization, 2006). These three indices (low height-for-age, low weight-for-age and low weight-for-height) are not mutually exclusive and usually coexist, which makes for unclear interpretation. For example, as child weight is compared to standardized age distribution, there can be no difference between short children of normal body weight and tall, thin children. It is argued, therefore, that conventional indices are not sufficient for measuring the overall prevalence of undernutrition, and that we should construct a new aggregate of indicators such as the composite Index of Anthropometric Failure (CIAF). Nevertheless, underweight is a critical risk factor that could worsen the illness and deteriorating nutritional status as it exacerbates the risk of having malaria, diarrhoea and respiratory infections (Caulfield et al., 2004).

2.2.4 Overweight

Overweight among children aged under five years is defined in two ways; overweight (weight-for -height >+2 SD above the WHO child growth standards median) or overweight for age (weight-for -age>+2 SD above the WHO child growth standards median). Child overweight and obesity (weight-for-height >+3 SD above the WHO child growth standards median) is found to be a striking form of malnutrition at the global level. Childhood overweight has associations with an elevated risk of overweight and obesity in adulthood with increased possibilities of having diet-related non-communicable diseases later in life. World literature has given considerable attention on how overweightness in childhood has continued into adulthood (Barker, 1994; Minh Do et al., 2018). The impact of nutrition before birth and in early childhood on health throughout the life course has been examined in work done by Barker and Osmond (1986). The result is known as "Barker's fetal origin of adult diseases hypothesis" (Barker, 1994), which is subsequently developed as the Developmental Origins of Health and Disease (DOHaD). This theory postulated "fetal programming" or how inadequate nutrition *in utero* programmes the foetus to have metabolic characteristics that can lead to future diseases, given a complex interplay between genetic, developmental environmental, social and cultural factors. Barker claimed that foetal undernutrition in early life outside the womb programmes an infant to put in a risk of having cardiovascular problems in adult life (Barker, 2012; The Lancet, 2001). Notwithstanding the importance of theory, some studies argued that the theory could be expanded by investigating environmental influences during gestation on later development, in addition to focussing on genetic and more proximal factors as causes of adult disease (Skogen and Øverland, 2012). Moreover, this theory has given a space to further examine the cumulative nature of the risks that may occur during gestation, infancy, childhood and, adolescence (Almond and Currie, 2011). The fetal origin hypothesis has been kept in mind in investigating nutritional outcomes in early life as this may be a period critical for determining adults' health (The Lancet, 2001).

Today the number of overweight children has increased dramatically worldwide by 38 million in 2016 (UNICEF *et al*., 2017). The concentration is particularly high in Asia and Africa with almost half of all overweight children, aged under five years, living in Asia (46 per cent) and one quarter living in Africa (25 per cent) (UNICEF *et al*., 2017).

2.2.5 Maternal body mass index (BMI)

This thesis will also examine a core element of anthropometry, maternal body mass index (BMI) as a risk factor for low birth weight and child nutrition and as a measure of "double burden of malnutrition". BMI is defined as the weight in kilograms divided by the square of the height in metres (kg/m^2) (World Health Organization, 1995). It has been reported that more than 1.9 billion adults aged 18 years are overweight, while 650 million adults are obese. The prevalence of overweight among women is a key concern as it predisposes them to a wide array of health issues such as diabetes and heart disease, as well as poor birth outcomes. On the other hand, women suffer chronic energy deficiency (BMI < 18.5) leads to low work productivity and reduced resistance to illness (Department of Census and Statistics, 2017). Obesity is strongly associated with the rapid increase of NCDs and the deaths related to NCDs occupy 40.5 million (70.1 per cent) deaths of the 56.9 million global deaths in 2016 (World Health Organization, 2020). The burden of deaths from NCDs is substantial in low and middle-income countries, with 78 per cent of all deaths and 85 per cent of premature deaths occur due to NCDs (Development Initiatives, 2020).

2.2.6 Low birth weight

Low birth weight (LBW) is a critical nutritional indicator at birth which has profound implications for physical and cognitive growth in later life. LBW refers to those children born with a birth weight of less than 2.5 kilograms (< 2,500 grams) in line with WHO recommendations (World Health Organization, 2006). The cut-off point of 2,500 grams was established after many debates. In the early 1930s, birth weight was used as the definition of prematurity. The WHO expert group on prematurity proposed a definition for prematurity as having a birth weight ≤ 2,500 g at the World Health Assembly in 1984. Subsequently, low birth weight was defined as < 2,500g and this is now used as the universal birth weight cut-off (Hughes et al., 2017). For the present study LBW is considered as equal to or more than 2500 grams due to the heaping on reported birth weights of 2,500 grams, to avoid underestimate the proportion of LBW babies.

2.3 Associations between maternal anthropometry and offspring outcomes

It has been found that maternal BMI level and weight gain during pregnancy are closely associated with child nutritional status (Ohlendorf et al., 2019; Tigga and Sen, 2016). Maternal underweight was another risk factor in determining low birth weight and poor child nutritional status (Martins *et al*., 2011; Victora *et al*., 2008). This is often called as the "vicious cycle of malnutrition" or the "intergeneration cycle of growth failure" between maternal stature and childbirth outcomes. Women who are undernourished during pregnancy are at a higher risk of having a low birth weight or a small-for-gestational-age infant. These offspring could potentially be at an elevated risk of being stunted and wasted during their early years, may not perform much catch-up growth in subsequent years, and be vulnerable to various diseases. In this way, undernutrition is transmitted across generations through the mother (Ahmed et al., 2012; Arlinghaus et al., 2018). Maternal height is often highlighted as the strongest predictor of the intergenerational linkages between maternal and child nutrition and health; thus infants of a short mother (height <145) are two times more likely to exhibit stunting and 1.2 times more likely to exhibit wasting compared with children of the tallest mothers. Further, from the evidence of 54 LMICs, it is found that maternal stature was inversely associated with child stunting and underweight, the decreased risk of stunting and underweight associated with a 1 cm increase in material height (Ozaltin et al., 2010).

Alongside the intergenerational effects of poor nutrition, countries are today facing an emergence of the double burden of malnutrition, by adding maternal obesity and related chronic diseases to the public health agenda. Obesity increases the risk of gestational diabetes mellitus (GDM) and this, in turn, contributes to having obesity and diabetes in the children as well as the risk of diabetes in the mother that could affect her future pregnancies. Thus, over time, this intergenerational effect could increase the prevalence of obesity and diabetes in the population. The challenge posed is to promote linear growth in the first 1,000 days, prevent wasting and avoid overweight after the age of two, so as to break the intergenerational cycle (Martorell and Zongrone, 2012). Thus, countries' nutrition agendas are giving increasing attention to recognizing socioeconomic, nutrition and health conditions throughout the life cycle that could possibly be helpful to break the intergenerational cycle (Martorell and Zongrone, 2012; Sivasankaran, 2014).

2.4 Nutrition transition: the emergence of a double burden of malnutrition in low- and middle-income countries

There is growing attention on the emergence of the double burden of malnutrition in LMICs. (Development Initiatives, 2020; Popkin et al., 2020).

Historically, undernutrition has been linked with greater occurrence of infectious diseases at the times that populations underwent a sequence of epidemiologic, demographic and nutrition transitions. In the demographic transition, societies who are characterised by pre-industrial, predominant agrarian economies advanced towards industrialized societies, characterised by lengthening life expectancy and fertility decline, which are observed to be the main drivers of this distinct epidemiological transition. The epidemiological transition constitutes a shift in the overall population disease burden paralleled with high mortality and fertility level to lower mortality and fertility. The shift also has involved a lessening of the dominance of infections and diseases related to undernutrition in favour of rising rates of deaths from NCDs (World Health Organization, 2018a). The nutrition transition describes the shift in dietary patterns, changes in the consumption of the diet and reduced energy expenditure associated with economic development over time, given the context of globalization and urbanization (Popkin et al., 2020; World Health Organization, 2018a).

Popkin (2003) has identified five stages or ‘patterns’ of the nutrition transition: collecting food, famine, receding famine, degenerative disease, and behavioural change. In the first *Paleolithic* pattern, the diet was abundant in healthy substances, however, nutrition-related diseases and deaths from other natural causes result in a very short life span. In the second stage, the nutritional status of the population deteriorated due to famine. In the third stage, famine begins to recede as incomes rise. People tend to consume home food production that requires a greater amount of physical activity related to planting and harvesting. The fourth pattern encompasses the change in dietary patterns and activities that leads to the onset of new diseases and increases disability. People get more energy-dense foods with increased sugar consumption. There is a reduction in agriculture-based labour and household labour, resulting in people relying on processed foods produced outside the home. The final stage is characterised by a shift in the behaviour and dietary patterns with people tending to increase the intake of nutritious foods and reduce consumption of processed foods (Popkin, 2003).

An increasing amount of literature shows that countries currently experience various stages of the nutrition transition but that most lie in the fourth pattern, while North America and Northern and Southern Europe may be moving into the final stage (Food and Agriculture Organization of the

United Nations, 2006). However, unlike developed nations, who experienced the different patterns of the transition gradually, the transition of many LMICs countries has been rapid. This rapid transition in developing countries has produced a unique situation of a double burden of malnutrition, in which undernutrition, overnutrition and obesity coexist within the same population and in some instances, the same household or even individual, accompanied by the rise of BMI and NCDs such as cardiovascular disease, type-2 diabetes and cancers.

The escalation of NCDs presents multiple threats to society including an unendurable pressure on health care services which are predominantly government-funded. Moreover, the increase in NCDs in LMICs has been unevenly distributed amongst poor and disadvantaged populations, contributing to widening health gaps between and within countries. For example, NCDs and obesity, which are largely associated with higher socioeconomic status in transitioning economies, are now increasingly marked amongst population sub-groups who are in a lower socioeconomic position. Evidence from studies conducted in LMICs has shown that people in a lower socioeconomic position have an elevated risk of being overweight or obese or suffering the paradoxical double burden compared to the households with higher socioeconomic status (Jehn and Brewis, 2009; Popkin et al., 2020).

It has been reported that this paradoxical situation is more likely to be linked with rapid urbanization. This has been directly influenced by an increase in the GDP and the purchasing capacity of individuals with urbanization, subsequently influencing changes in lifestyles, dietary patterns and a shift from labour-consuming work to more sedentary work styles. Urban populations are likely to consume foods with little nutritional value such as processed foods high in saturated fats, cheap edible oils and caloric sweeteners (Food and Agriculture Organization of the United Nations, 2006). Thus, according to Popkin (2003), the affordability of these foods stimulates dietary changes that could obviously result in the replacement of nutritious foods among these populations. However, in contrast with the fact that double burden child-mother pairs are always seen in urban areas, some studies have claimed that the coexistence is not necessarily associated with living in an urban area, and that economic development (as represented by GDP per capita), socioeconomic status and lifestyle factors, such as affordability of nutritious foods are more pronounced in determining underweight or overweight of a population (Garrett and Ruel, 2005; Griffiths and Bentley, 2001; Popkin, 2003). Since the distinctive double burden of malnutrition happens across the life course, it also highlights the importance of the nutrition in early life. There is evidence from the developmental origins of disease paradigm that undernutrition during pregnancy and early life predispose a person to an elevated risk of developing obesity and NCDs like diabetes later in their life. This could be applied to the present context of DBM

Thus, it makes sense to believe that interventions should be taken to promote maternal, infant and child nutritional status in order to establish a healthy path from the start of life.

2.5 Socioeconomic inequalities in child undernutrition at the global and regional level

Countries with the highest prevalence of stunting and wasting in children under the age of five years also have the highest proportions of disadvantaged populations (the poorest, the least educated and the most residing in rural areas) (UNICEF et al., 2017). For example, in 2016 more than half of all stunted under-five children lived in Asia and 38 per cent lived in Africa whilst more than two-thirds of under-five wasted children are accounted for 69 per cent in Asia and more than one quarter (27 %) of wasted children lived in Africa (UNICEF et al., 2017).

Further, within these regions, substantial inequalities are visible among population subgroups (Bain et al., 2013; de Onis and Branca, 2016). In most countries, the prevalence of underweight and stunting among children aged under five years is about 2.5 times higher in the lowest wealth quintile compared with the highest (Black et al., 2013). Gender inequalities are also visible among children who are stunted: boys are more likely to be disadvantaged than girls (de Onis and Branca, 2016). The residential status also represents an important factor in child stunting with rates constantly higher in rural than in urban areas (de Onis and Branca, 2016; Fotso, 2006; Senbanjo et al., 2013).

Another study conducted on the nutritional status of children in 47 developing countries revealed that socioeconomic inequality in childhood malnutrition existed throughout the developing world; however, poor children are more susceptible to being highly wasted or stunted (Van de Poel et al., 2008). It can be concluded that even though the prevalence of malnutrition among children who are under five years old has decreased over time, it remains unsatisfactory for some regions, particularly in Asia and Africa, and reflects divergent patterns across the regions.

The highest levels of stunting in the world are found in the South Asia region, particularly in India, Pakistan, Bangladesh and Nepal (UNICEF, 2017; World Health Organization, 2007). Studies focused on differentials in child health and nutritional outcomes tend to reveal socioeconomic differentials in child health and nutrition outcomes at the national level which are directly linked to the socioeconomic and demographic characteristics of a population (Akhtar, 2016; Mohammad et al., 2016; Thakur et al., 2011).

In India, which has one of the largest number of stunted children in the world, regional analysis on child malnutrition found substantial heterogeneity in coefficients for maternal and child nutrition across states (Cavatorta et al., 2015). For instance, Tamil Nadu shows a good performance in child nutritional level compared to Bihar, Madhya Pradesh and Uttar Pradesh (Cavatorta *et al*., 2015). Another study also recognized significant variations in the results of child nutrition across states. For example, nearly 51 per cent of children are recorded as underweight in Bihar, Madhya Pradesh, Orissa and Uttar Pradesh, Assam and Rajasthan; however, Goa, Kerala and Punjab exhibited a relatively low prevalence of malnutrition (Akhtar, 2016; Thakur *et al*., 2011). The mother's weight and age at childbirth, education and nutritional status of the mother displayed a strong positive correlation with child nutritional status in these states (Akhtar, 2016; Cavatorta *et al*., 2015; Thakur *et al*., 2011).

Likewise, in Pakistan, the highest rate of child malnutrition found in individual districts ranged from about 22 and 76 per cent. The lowest prevalence is among the wealthy population of Islamabad while the highest was seen in districts near to the Afghan border. Child stunting levels are highly associated with food insecurity in each district (Cesare *et al*., 2015).

Bangladesh is ranked as one of the poorest countries with the highest rate of malnutrition. Evidence shows malnutrition continues as a vicious cycle. Malnourished mothers give birth to malnourished infants, and when these infants grow up they in turn, become malnourished mothers (Akhtar, 2016). Two studies that used concentration indices and a decomposition method to estimate socioeconomic inequality in child malnutrition in Bangladesh found an increase in inequality among urban children compared to rural children (Huda et al., 2018; Mohammad et al., 2016). In Mohammad *et al.*'s (2016) study, the concentration curve lies above the line of equality for child stunting and wasting: inequality was almost two times higher for urban children (Mohammad et al., 2016). Variables such as household economic status, parental education, health-seeking behavior of the mothers, sanitation, fertility and maternal stature explain disparities in stunting prevalence in Bangladesh (Huda et al., 2018; Mohammad et al., 2016).

Even though it is child undernutrition that has dominated the country's development, a few recent studies in Bangladesh indicate that country has undergone a double burden of malnutrition with the additional presence of overweight and obesity among half of all adult women (Khan and Talukder, 2013; Mascie-Taylor, 2012). Mother's age, area of residence, education and wealth index have been found to have a significant influence on their nutritional status (Hasan et al., 2017; Khan and Talukder, 2013).

Nepal is another South Asian country where child malnutrition remains a problem of public health significance and one of the major causes of child morbidity and mortality. Even though regional disparities in malnutrition are apparent in DHS data from 1996, 2001, and 2006, the causes of such disparities are less likely to be addressed in the literature (Bishwakarma, 2011). According to DHSs in Nepal, wide disparities of child undernutrition could be seen across different socioeconomic groups and regions. For instance, children from the poorest households are more than twice as likely to be stunted (56 per cent) compared to the children in the wealthiest households (26 per cent). Similarly, children in rural areas are more likely to be stunted (42 per cent) than those in urban areas (27 per cent), and ecologically, the mountain zone has the highest proportion of stunted children (53 per cent) (Bredenkamp et al., 2014; Devkota et al., 2016). These studies also have identified the inadequacy of appropriate foods as a potential determinant of the prevalence of malnutrition in Nepal where hunger and poverty drive conditions leading to malnutrition (Akhtar, 2016; Cunningham et al., 2017; Devkota et al., 2016).

From the literature on South Asian countries, it appears the occurrence of malnutrition may vary within different communities and households. Nevertheless, this evidence shows that socioeconomic inequality in childhood health and nutrition exists in these countries. Therefore, more studies should be conducted to capture inequalities in child nutrition in order to inform appropriate strategies to reduce these inequalities among different socioeconomic groups.

2.6 Research gaps in child undernutrition and DBM in Sri Lanka

Over the decades, the lack of improvement in child nutrition in Sri Lanka has encouraged national researchers to examine the factors underlying child nutritional outcomes. The majority of studies have been small scale or restricted to only specific socioeconomic or residential sectors (Herath, 2016; Jayawardena, 2014; Karthigesu et al., 2016). Irrespective of this potential limitation, these studies concluded that child malnutrition is a public health challenge that remains unresolved in Sri Lanka (Jayasekara and Schultz, 2007; Jayasinghe, 2010; Jayawardena, 2014). According to Houweling *et al*. (2007), advancement in health care use and declining levels of malnutrition in Sri Lanka ran parallel with high and increasing relative inequalities in health care and malnutrition.

A few national studies conducted on the determinants of child undernutrition have indicated that household factors are significant predictors (Jayawardena, 2014; Rannan-Eliya et al., 2013). A study using probit analysis on maternal and child nutritional levels in the estate sector found that household sanitation and household socioeconomic factors were significantly associated with child and maternal malnutrition. This study further highlighted that food insecurity, alcoholism and also a lack of education and knowledge amongst women appeared to increase the mothers' and children's susceptibility to malnourishment (Jayawardena, 2014). Both national level and sectoral studies place significant emphasis on the importance of sanitary facilities, safe drinking water, access to piped water and electricity for child weight, height and nutrition in the community (Aturupane et al., 2008; Galgamuwa et al., 2017). Children who have the highest risk of malnutrition need specialised interventions (Aturupane *et al*., 2008); thus, health education programmes are suggested as an effective solution (Galgamuwa *et al*., 2017).

Household wealth or income is identified as one of the key factors influencing child nutrition in some national and regional studies (Jayawardena, 2014; Karthigesu et al., 2016; Liyanage, 2016; Rannan-Eliya et al., 2013). These studies reveal that the prevalence of malnutrition and anaemia decrease as wealth increases, increasing monthly household income was significantly associated with lower rates of stunting and underweight (Liyanage, 2016). Further, these studies claim that poor children are highly vulnerable to diseases due to poor resistance and lower coverage of preventive interventions compared to rich children.

Household expenditure on food has been found to be an important indicator of child nutritional status. The prevalence of undernutrition was significantly associated with expenditure on food as a percentage of total household expenditure, a lower dietary diversity score, and the adoption of food-related or non-food related coping strategies. Food-related coping strategies include borrowing food or reducing meal sizes while non-food coping strategies are borrowing money from relatives/neighbours, pawning jewellery and using savings (Karthigesu et al., 2016). Studies consistently highlight food security as a predominant factor in ensuring the health status of children (Herath, 2016; Jayawardena, 2014; Liyanage, 2016).

Sri Lanka is an island at higher risk of natural disaster effects such as droughts, floods and landslides. According to estimates, nearly 1.2 million people in 20 out of 25 districts were affected by prolonged drought in 2016-2017 due to poor rainfall in the year 2016 (Taylor, 2016). This poses a severe threat to the food security, nutrition and income levels of the population as the drought led to the loss of crops and agricultural labour opportunities (Institute of Poverty Analysis, 2018). Food insecurity causes a higher prevalence of wasting, underweight and anaemia among children compared to those in food secure households (Aturupane et al., 2008; Karthigesu et al., 2016). Nevertheless, Amarasinghe et al. (2017) argue that sex, monthly income and frequency of meat and green leafy vegetable consumption did not contribute significantly to variations in the anaemic level in children.

Sri Lanka has the highest rate of breastfeeding (Agampodi et al., 2009) and complementary feeding practices starting at 6–8 months of age (84 per cent) compared with other Asian countries (World Health Organization, 2017a). However, Rannan-Eliya et al. (2013) argue that there is no significant relationship between most IYCF indicators and child stunting whilst household wealth has significant impact on child undernutrition. This study further found that only continued breastfeeding for at least 12 months had a positive association with child stunting after 23 months. In addition, it is also reported that children who lived in the tea estate sector are reported to have the lowest diversity in feeding practices compared to urban and rural children (Senarath and Dibley, 2012).

Studies also highlight parental characteristics such as educational level and employment as influential factors for child nutritional outcomes (Aturupane et al., 2008; Galgamuwa et al., 2017; Herath, 2016; Jayawardena, 2014). Lack of parental education, identified as a risk factor for child undernutrition, which is interlinked with low birth size among children in Eastern Province in Sri Lanka (Herath, 2016). A cross-sectional study carried out in the plantation area found that children whose household heads were economically empowered tended to be better nourished than other children (Galgamuwa *et al*., 2017). Further, maternal and child factors such as BMI, maternal height, teenage pregnancy and duration of breastfeeding are among the significant determinants of child health and nutritional outcomes (Amarasinghe et al., 2017; Anuranga et al., 2012; Galgamuwa et al., 2017).

It is also revealed that girls are more disadvantaged than boys in terms of the risk of malnutrition (Aturupane *et al*., 2008). However, the same study, which used a quantile regression approach to find out the determinants of child nutrition, argues that neither parental education nor income growth is effective for children in the lower distribution of height and weight (Aturupane et al., 2008). The impact of child malnutrition was found by several researchers to cause lower academic performance, vulnerability to infections and negative effects on cognitive development, as well as influencing economic productivity when these malnourished children become adults (Houweling et al., 2007; Liyanage, 2016; Wisniewski, 2010). Many studies highlight that since the causes of malnutrition are multi-faceted, proper mechanisms should require strengthening of nutritional interventions (Aturupane et al., 2008; Jayawardena, 2014; Rajapaksa, 2011).

A number of studies have found that disparities exist which are associated with the socioeconomic and residential sectors (Amarasinghe et al., 2017; Anuranga et al., 2012; Fernando, 1999; Jayawardena, 2014). For instance, poor children living in the estate (plantation) sector or in the rural sector have less access to health facilities than those in the urban sector

(Jayawardena, 2014; Rannan-Eliya et al., 2013). There is a sense that ethnic minority groups who are in conflict-affected districts are being “left behind” despite efforts made by the government to achieve expected health and nutritional outcomes.

The findings of the literature review contribute to this study to identify a combination of socioeconomic factors that relate to determining the nutritional status of a child in Sri Lanka. Whilst some of these studies have analysed child nutrition, such analysis has not explored the multiple level factors determining child malnutrition. These studies only attempted to capture a limited number of socioeconomic variables, primarily household income and expenditure. Further, they failed to explore factors such as role of immunisation and access to health care facilities instead of income and educational status, all of which have been studied in other Asian contexts and at the global level. Moreover, less attention has been given to the influence of place of residence on child nutritional outcomes, even though there are significant variations in these outcomes across different residential sectors and districts. Therefore, these findings echo the need to analyse factors that could have been driving the inequalities of child malnutrition outcomes, giving considerable attention to ethnicity and residential sectors.

2.7 Policies and programme response to child malnutrition in Sri Lanka

The Government of Sri Lanka and other agencies initiated several efforts to address the underlying causes of malnutrition and achieve food security for its citizens. Despite all endeavours, improvement of nutritional status remains a challenge, even though Sri Lanka has lower levels of undernutrition compared with other South Asian countries. Given the burden of malnutrition in Sri Lanka, it is important to identify sufficient resources have been allocated for adequate nutrition activities. Therefore, this section assesses key policies and programmes that have been implemented and briefly reflects what mechanisms exist to identify overall gaps in the implementation of these policies.

The National Food and Nutrition Policy (2006-2010) was formulated to address the emerging problems in child undernutrition and regional disparities in nutritional indicators. This policy spells out three broad strategies: direct food assistance, an integrated package of maternal health and nutrition services under the Ministry of Healthcare and Nutrition as well as and poverty reduction programmes.

2.7.1 Direct food assistance and supplementary feeding programmes

These programmes are designed to prevent and address the nutritional deficiencies of all children and mothers. In terms of feeding and food assistance, different initiatives (including school feeding programmes) are aimed at poor children. These include a preschool nutrition programme targeted at children aged 3-5 years who are attending preschools; and *Thriposha* (triple nutrient)—the Government of Sri Lanka's major food supplementation programme—targeting pregnant and lactating mothers and their children aged 6-60 months, whose weight-for-age lies below -2SD. The distribution of micronutrient supplementation programmes also implemented that distribute Vitamin A, iron and Zinc supplementation for young children who are aged 6-59 months.
The school feeding programme is another initiative funded by the Government aimed at children from low-income families. The programme includes delivering prepared meals to public school children, providing "in-kind" school meals, wherein food ingredients are brought to the schools and prepared at the school for distribution including milk or yoghurt (The World Bank, 2015b). Under the preschool meal programme, "*Tikiri Shakthi" (*a protein nutrition bar) is providing for the estate sector children aged 3-5 years (Higashi et al., 2020). The other programme is the *Poshana malla* (nutritious basket of food) initiated by the government in 2006 targeting pregnant and lactating mothers from low-income families.

2.7.2 Integrated maternal and child health (MCH) and nutrition programme

The MCH programme is mainly integrated with maternal and child health services, which have a broad scope in providing antenatal, intrapartum and postnatal care for mothers. Under this programme, the nutrition steering committee (NSC) has been established in 2007 to coordinate properly with government, health and non-health sectors.
The role of public health midwives is crucial in the MCH programme. They provide nutrition education and counselling services for mothers, they keep track of and follow up on weight gain through pregnancy records, they monitor the growth of children to identify exposure to the risk of malnutrition, and they are involved with the provision of micronutrient supplements (iron, folic acid, calcium and vitamin C) during pregnancy, and the provision of *Thriposha*.
Overall, there are some gaps in Nutrition-Specific interventions such as poor geographic coverage, access to the services (especially in the estate sector) and lastly, the absence of data on the performances of existing interventions to assess the efficiency of these programmes.

2.7.3 Programmes on poverty alleviation

The Government of Sri Lanka introduced a poverty reduction initiative referred as *Samurdhi* (prosperity) in 1995, a forefront programme initiated to offer social economic and welfare assistance to the poorest and most vulnerable people (Center for Public Impact, 2019; Glinskaya, 2016). This provides financial support ranging from Rs.100 up to Rs.3,500 (US$ 0.5-20) per month, depending on family size and household poverty level. This income supplement can be used to purchase food items such as grains, cereals, and legumes. In addition to the government's *Samurdhi* programme, some non-governmental organisations (World Vision, Save the Children, etc.) are involved in poverty reduction activities including nutrition awareness programmes. Despite all these endeavours, key challenges remain in terms of reducing the burden of child malnutrition. Further, for the policymakers, it would be beneficial to identify vulnerable groups and patterns of socioeconomic inequalities in order better to target interventions aimed at reducing inequality in child malnutrition outcomes.

2.8 Conceptual frameworks related to the study

This section will review the two conceptual frameworks, reflecting relationships among individual, maternal and socioeconomic factors and their influence on child nutritional status.

A child’s nutritional status is determined by a broader context of social, demographic economic and environmental factors which are closely and indirectly associated with the child. Due to the broader complexity of factors associated with child nutritional status, conceptual frameworks have been frequently used to graphically represent how different factors interact in pathways to result in the child having good or poor nutrition.

Two frequently used conceptual frameworks for the socioeconomic determinants of undernutrition have been proposed by Mosley and Chen (1984) and by UNICEF (2013). These are shown in Figures 2.1 and 2.2.

Mosley and Chen (1984) argued that both child mortality and child growth are influenced by the same set of fundamental nutritional and infectious conditions, for instance, weight-for-age can be considered as a measure of health status rather than merely of nutritional status (Hill, 2003; Mosley and Chen, 1984).

The model assumes that in an optimal setting, over 97 per cent of newborn infants are expected to survive through the first five years of life, thus, any reduction in the survival probability is due to the functioning of social, economic, biological and environmental forces. Mosley and Chen summarised these factors in a conceptual framework with two major levels; distal and proximate factors depending on their proximity to the outcome of mortality or growth faltering (Hill, 2003; Mosley and Chen, 1984). They have identified five sets of proximate determinants that directly influence child mortality. These are maternal factors, environmental contamination, nutrient deficiency, injury and personal illness control (Mosley and Chen, 1984) (Figure 2.1). These proximate determinants control the health dynamics of population, specifically, the shift of healthy people towards sickness. The risk factors proposed by Mosely and Chen are multifaceted, which helped the present study to understand several factors influencing the nutritional status of children.

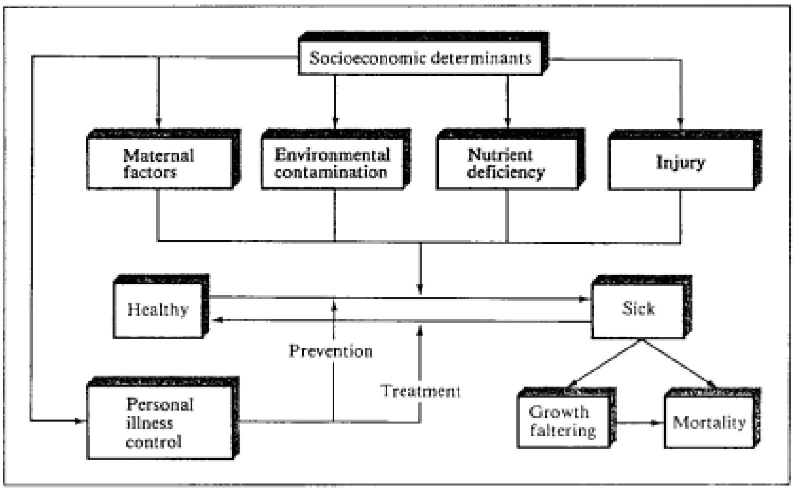
Thus, the present study incorporates proximate determinants such as maternal age, birth interval and child health factors that directly impact upon the nutritional status of children. In addition, this study captures maternal nutritional status, measured by the maternal anthropometric measures such as BMI and height which shown to be directly linked to the main outcomes of this thesis which are nutritional outcomes of infants (low birth weight) children and mothers (double burden of malnutrition).

Mosely and Chen framework also consists of socioeconomic determinants including mother/father variables, household-level variables such as income/wealth, water, preventive care; and community variables such as the ecological setting, political economy and health system. These are distal factors exert through the proximate determinants to influence growth faltering and child mortality. Socioeconomic determinants illustrated in three groups defined by levels of aggregation: individual, household and community level. Thus, it presents a multilevel nature, where direct and indirect factors operate at multiple levels to influence child nutrition which is employed by the present study.

This framework of the present study incorporates socioeconomic variables, which can be referred to as intermediate factors which are operating mainly at the household level. As an intermediate factor, household wealth measured by wealth index is considered to influence child nutritional status through its influence on both material conditions and behavioural factors including access to adequate and nutritious food and health care (Hong et al., 2006).

However, it is argued that Mosely and Chen model has not included possible child risk factors such as low birth weight, hence the users of this model are unable to establish what is meant as a proximate determinant (Hill, 2003). Furthermore, the recent reduction in child mortality rates in developing countries due to the decline in the proportions of malnourished children and the interventions that affect maternal factors such as promote space between children, have not been included in this framework (Pavitra et al., 2018)

Figure 2.1 Five sets of proximate determinants of child health and mortality presented by Mosely and Chen, 1984.



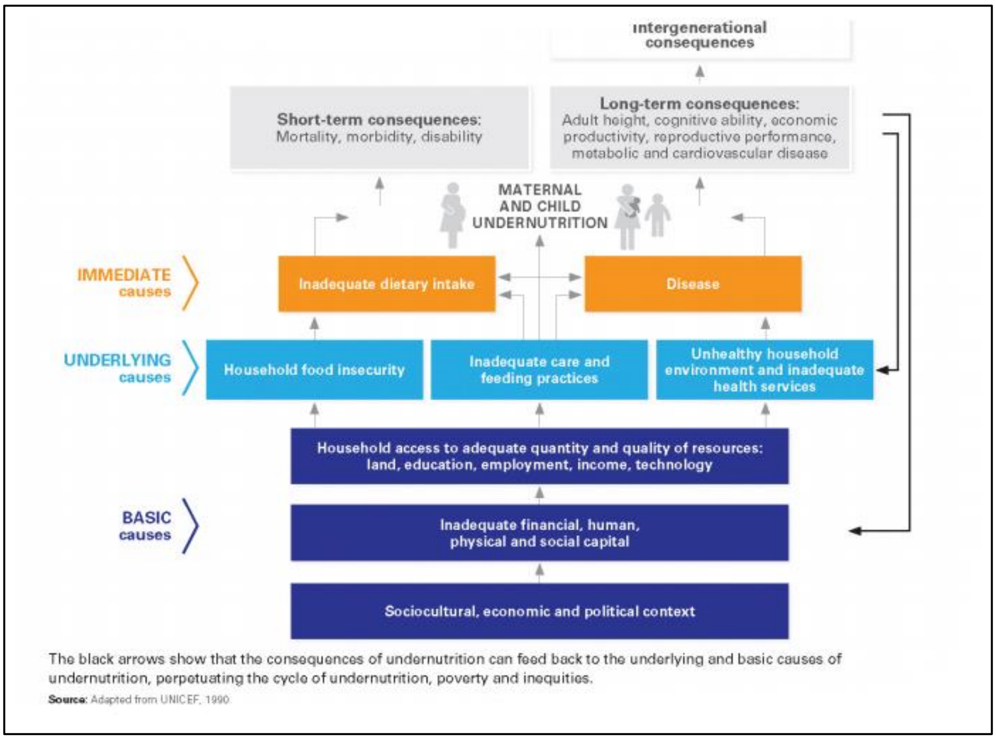
Original source: Mosley and Chen, 1984, pp.29

The framework underpinning this analysis is also based upon the framework proposed by UNICEF. The UNICEF's conceptual framework recognises the basic, underlying and immediate causes of undernutrition in developed and developing countries (Bishwakarma, 2011; Reinhardt and Fanzo, 2014; UNICEF, 2013) (Figure 2.2).

It shows that while immediate causes of malnutrition causes are at the individual level through inadequate dietary intake and disease, underlying causes such as household food insecurity, inadequate care and feeding practices for children, unhealthy household environments and inadequate health care, are the result of the basic causes. At the broader societal level, the political, economic and ideological structures indirectly affect behaviour within the household. This conceptual framework also represents the consequences of undernutrition in the short and long term. In the short-term, undernutrition increases the risks of mortality and morbidity. In the long term, it is associated with adulthood risks such as impaired cognition that result in poor school performances which, in turn, lead to poor earning power at the individual level and reduced economic productivity at the national level (Hoddinott et al., 2008). This framework highlights the intergenerational cycle of malnutrition (Ozaltin et al., 2010). The undernourished women are at a higher risk of obstetric complications and deliver offspring with low birth weight. This shows the future risks for the overweight and non-communicable diseases that can occur at individual levels over the life course (Reinhardt and Fanzo, 2014; UNICEF, 2015).

Although UNICEF's framework is crucial in identifying the multifactorial determinants associated with child nutrition at the community, household, and individual levels, it is not entirely adequate to investigate the research objectives of this study. For instance, there is no theoretical framework for child malnutrition that recognises paradoxical malnutrition outcomes such as child undernutrition and maternal overweight and obesity. The present study examines the sequence of low birth weight, child undernutrition and the double burden of malnutrition by investigating how bio-behavioural, socioeconomic and demographic factors account for socioeconomic inequalities in three interrelated papers. Hence, there is a need to design a more comprehensive framework that encompasses individual, maternal, household and geographic levels that address the spectrum of malnutrition. This includes low birth weight, child stunting, wasting, underweight and the coexistence of child stunting and maternal overweight/obesity in the same household while giving special consideration to the context of Sri Lanka.

Figure 2.2 The UNICEF conceptual framework on nutrition



Source: UNICEF, 2013, pp.4 (Adopted from UNICEF,1990)

2.9 Analytical frameworks of the present study

This study develops a general analytical framework to address the research outcomes of each chapter, low birth weight, child undernutrition, and the double burden of malnutrition at the household level. The arrows identify the pathways that are examined throughout each respective chapter.

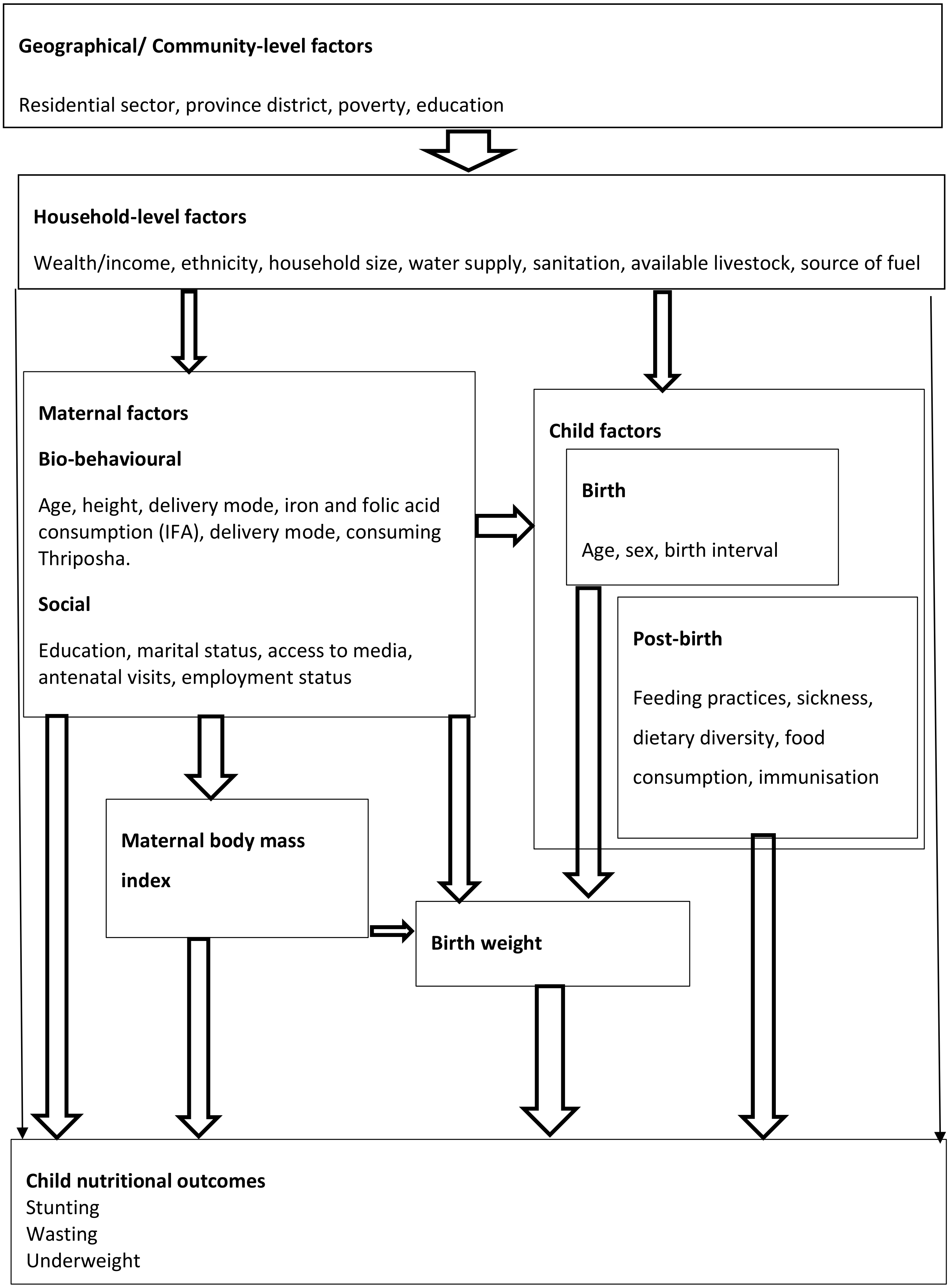
The factors associated with healthy growth and development in young children described in the previous Mosely and Chen and UNICEF conceptual frameworks bear similarities to the factors described in the analytical framework for this study. Adapted from the UNICEF framework on the hierarchical organisation of the different societal levels, it highlights three distinctive sets of factors, immediate (proximate), intermediate and distal which incorporate child, maternal, household and community level factors. The model suggests that the distal factors affect intermediate factors, which in turn affect the immediate factors, in turn affecting the child's nutrition status. This analysis used this analytical framework to structure the hierarchical multiple regression analyses.

At the bottom of the framework are shown the immediate factors (operating at the individual level and maternal level). These include bio- behavioural and social factors and, among the child factors, there are birth/institutional factors and post birth factors. Maternal and child factors are placed at the same level as they are related and strongly influence the final outcomes. Maternal BMI and birth weight variables given key attention as they play both roles in Chapter 4 and 6 outcomes and also play a significant role in determining child nutritional outcomes (Chapter 5).

On the other hand, intermediate factors that operate at the household level are those which may be directly associated with childbirth weight, undernutrition and DBM at the household level. These factors are related to characteristics of ethnicity, household wealth, environment, which are likely to be influenced by socioeconomic conditions. For instance, biological factors such as maternal BMI and birth weight of the child play a direct and a crucial role in influencing a child's growth outcome whereas household level factors such as access to resources such as household income, access to water and sanitation are important at influencing child overall health outcomes and therefore play an indirect role in influencing child's anthropometric measures.

At the very top of the framework, pertaining to the distal factors (community), are a range of geographic/residential factors, including residence, province and community poverty and average levels of maternal education. These factors mostly act through other intermediate and immediate level factors to influence outcomes that will be of interest. Although this framework presented an overarching picture of factors associated with child health, undernutrition outcome and DBM at the household level, it is not fully comprehensive, i.e., there may be other factors which are not considered. Overall, this framework is used as a tool in respective chapters for examining interrelated trajectories that can be associated with low birth weight, children undernutrition outcomes and the DBM, in association with distal, intermediate and immediate factors lie at the different levels.

Figure 2.3 General conceptual /analytical framework of the study showing the pathways through which distal, intermediate and immediate factors influence nutritional status outcomes



2.10 Factors associated with child malnutrition

This section mainly focuses on determinants in the conceptual framework that are drawing connections between the immediate, intermediate and distal factors known to be associated with the main outcomes of the thesis. Factors that are specifically relevant to each outcome are discussed in each paper in more depth.

2.10.1 Child level factors

With reference to the immediate child factors, low birth weight (birth weight < 2,500 grams) has been found as a well-established risk factor for mortality and morbidity among children aged under five years. Many determinants of birth weight and child nutritional status are interchangeable, as birth weight is a strong predictor of child undernutrition and at the same time maternal BMI is a predictor of low birth weight (Mohanty *et al*., 2005). Birth weight is also relevant in terms of understanding the susceptibility to health and diseases in later life, which is known as the “Developmental origins of health and disease” effect. This explains how birth weight and subsequent early growth during infancy and childhood are affected by the foetal programming that occurs in the intrauterine environment: low birth weight may be followed by diabetes and obesity in adult life. Thus, it is evident that epidemics of such diseases of adult life have a U-shaped association with birth weight; increased rates in both the lower and upper parts of the range, each reflecting different causal pathways (Diamond, 2003; Newnham, 2007).

Previous works also have been defined “catch up growth” of low birth weight children catch-up growth defined as an improvement in height-for-age or recovering from stunting or catch-up in linear growth. In other words, catch-up growth could happen if the height-for-age difference (HAD) is declined (Crookston et al., 2010; Desmond and Casale, 2017; Mendez and Adair, 1999). A number of studies documented a catch-up in linear growth after 2 years of age among children who exposed to the standard care and feeding practices in the developing country contexts (Georgiadis and Penny, 2017).

There is considerable empirical evidence conducted at various settings to support a strong relationship between maternal factors and low birth weight. These determinants broadly range from genetic, constitutional, obstetric, and nutritional-related to maternal morbidities in the antenatal period, antenatal care (ANC) and other socioeconomic factors (Baghianimoghadam et al., 2015; Blanc and Wardlaw, 2005), which are broadly discussed in Chapter 4.

The effect of preceding birth interval on childbirth weight and child nutritional status is reported elsewhere (de Jonge *et al*., 2014; Rutstein, 2005). Birth interval is defined as the length of time between two consecutive births or, as DHS surveys tabulate it, as the percentage of births in the five years preceding the survey by specified grouped number of months since the preceding birth (Croft et al., 2018). It is found that longer birth intervals decrease the risk while short birth intervals (less than 21 months) are known to have a detrimental effect on pregnancy outcomes such as stillbirths (de Jonge *et al*., 2014; Rutstein, 2005). Furthermore, the birth interval may affect the child's nutritional level through influencing the amount of care and resources allocated to the present children as well as the maternal nutritional level (Dewey and Cohen, 2007). Short birth intervals are associated with maternal depletion, as a mother may have insufficient time to recover her nutrient reserves after the previous pregnancy (Dewey and Cohen, 2007; King, 2003). Children with longer preceding birth intervals are less likely to be malnourished, as their mothers' bodies have had sufficient time to recover from the pregnancy. Therefore, it is suggested to increase birth space between pregnancies in order to prevent adverse health outcomes and poor nutrition of children (de Jonge *et al*., 2014).

In terms of gender differences, evidence from numerous contexts (including LMICs) found that male children are more vulnerable than female children to poor nutritional outcomes, although the difference was often negligible (Black et al., 2008; Fatima et al., 2020; Wamani et al., 2007) or not reported any significant gender difference, particularly in weight-for-age scores (Griffiths et al., 2002).

Infant feeding is also regarded as an important predictor in child nutrition. According to the guidelines provided by WHO, exclusive breastfeeding is to be encouraged for the first six months and complementary feeding should be started thereafter (UNICEF, 2012). The first two years of infancy is regarded as a critical window to ensure children's appropriate growth. For instance, universal coverage of breastfeeding could contribute a 13 per cent mortality reduction of children aged under five years, while IYCF practices result in an additional 6 per cent reduction in under-five mortality (World Health Organization, 2019c). Compared to other regions, South Asia has made relatively good progress in breastfeeding practices (Torlesse and Raju, 2018). However, low household wealth, low levels of parental education (particularly fathers' education), a low frequency of antenatal visits and poor exposure to media are found as major barriers on feeding practices in South Asian counties including Bangladesh, India, Nepal, Pakistan and Sri Lanka (Senarath and Dibley, 2012). Similarly, in Sub-Saharan African countries and Latin American countries such as Colombia and Nicaragua, Peru and Guatemala child feeding practices are negatively associated with household income (Gebremedhin, 2019; Ruel and Menon, 2002). Prolonged breastfeeding in the context of LMICs, where children are breastfed for longer periods (up to two years of age or beyond) without the timely introduction of complementary feeding may result in childhood undernutrition and frequent illnesses (Akombi et al., 2017). Therefore, studies emphasised that adopting WHO recommended guidelines on feeding is one of the most proactive strategies for optimal nutrition and the prevention of mortality among children aged under five years (Bhutta et al., 2008; Gebremedhin, 2019; Mya et al., 2019).

The association between child illness and child undernutrition is also pronounced, malnourished children have an elevated risk of infectious mortality due to various infections, measles and tuberculosis. Hence the nutrition of the child and childhood infections have always been linked (Katona and Katona-Apte, 2008). This relationship causes a vicious cycle: malnutrition can make a child more susceptible to infections, and conversely, infections can contribute to malnutrition. Infections may weaken dietary intake, reduce the absorption of proper nutrients and increase the loss of nutrients. Hence, children who are unable to recover from their illnesses may be vulnerable to this vicious cycle of poor nutrition and health. Child undernutrition is acknowledged as one of the leading causes of immune deficiency worldwide among infants, children and even adults (Tariq et al., 2018). Five infectious diseases, namely pneumonia, diarrhoea, malaria, measles, and AIDS, account for more than half of all deaths in children aged under five years. It has also been reported that frequent episodes of diarrhoea exacerbate growth faltering in rural Malawian children aged 6-18 months (Weisz et al., 2011). Acute respiratory infections (ARIs) are another cause of poor child anthropometric measures, being associated with an elevated risk of 58 per cent for child underweight, and 54 per cent for child wasting (Mwiru *et al*., 2013). These studies concluded that there is a need to strengthen the quality, quantity and accessibility of nutritional services, more specifically the promotion of breastfeeding to reduce susceptibility to childhood infectious diseases.

To combat child infections and illnesses it is vital to provide a protective response such as vaccination. There is evidence that vaccination helps to prevent infectious diseases as it builds the immune system, which leads to increased child growth (Prendergast, 2015). Studies which examined the association between child anthropometric measures and vaccination found that higher child immunisation explains the lower prevalence of both wasting and stunting specifically in developing counties (Anekwe and Kumar, 2012). A cross-sectional study conducted in 35 low and middle-income countries showed a clear correlation between universal vaccination coverage and a low prevalence of wasting and stunting (Li et al., 2020). Studies in India found that a universal immunisation programme reduced child stunting by 22-25 per cent and it further reduced child wasting by 5 per cent (Anekwe and Kumar, 2012; Prendergast and Humphrey, 2014).This study concluded that the vaccination programme is a “high return investment” for child health (Prendergast, 2015).

2.10.2 Maternal factors

Maternal factors are identified as immediate factors which affect the final outcomes. Among maternal factors, maternal BMI prior to pregnancy, which is one of the critical factors in determining both child low birth weight and child undernutrition (Razak et al., 2013). (Wrottesley et al., 2017). For instance, in terms of the developmental origins of health and disease hypothesis maternal anthropometry during pregnancy has been accepted as a critical factor (Mandy and Nyirenda, 2018).

A pooled analysis of maternal height and offspring growth using five birth cohorts from Brazil, Guatemala, India, the Philippines, and South Africa showed that maternal stature influences linear growth of offspring over a growth period (Addo *et al*., 2013). According to the finding, short mothers (150 cm or less) were 3.2 times more likely to have a stunted child at age two years compared with taller mothers. This study further found that maternal height is associated with offspring's birth weight thus genetic factors, as well as non-genetic factors, such as environmental factors such as maternal nutrition, feeding practices, dietary quality and quantity, and infection are influenced on this association. Similarly, a study in Bangladesh (Felisbino-Mendes et al., 2014), analysing five Demographic and Health Surveys, found a reduction in child malnutrition associated with an increased maternal BMI (Hasan *et al*., 2016). Several studies, for example, Kulasekaran (2012) have found that women with poor nutritional status indicated by a low BMI, are more likely to have severely stunted, severely wasted and severely underweight children.

Some evidence can be found to support maternal height as a significant predictor of child anthropometric measures, more specifically children's height for age (Fleten et al., 2012; Negash et al., 2015). In addition, a population-based cross-sectional study in Brazil also observed how maternal and child anthropometry are positively associated, short mothers had children with lower stature and obese mothers had taller children (Felisbino-Mendes *et al*., 2014). A study in India also found a high correlation between a mother's BMI and the *z*-scores of the heights of her children. This indicates a strong genetic component between maternal and child anthropometry. (Tigga and Sen, 2016). Moreover, it is also reported among Chilean families, how maternal BMI is correlated with the BMI of both male and female children (Santos et al., 2009). Therefore it is suggested taking nutritional interventions such as increased intake of nutrient-rich foods, improved complementary feeding practices, micronutrient supplements and fortified foods during the first 1000 days of life (during pregnancy to the first 2 years) have a positive impact on maternal nutrition and child growth (Addo et al., 2013; Dewey, 2016).

A large number of existing studies have examined the effect of maternal age at the child's birth on child growth (Fall et al., 2015; Ganchimeg et al., 2014). A multi-country study conducted by the

World Health Organization, based on data from 29 African, Asian, Latin American, and Middle Eastern countries, found that adolescent mothers (10–19 years) were at higher risk of adverse birth outcomes such as low birth weight, compared with adult mothers (20–24 years) after controlling for covariates (Ganchimeg *et al*., 2014). This was in line with the results of another cohort study, that children of younger mothers (< 19 years) were more likely to be stunted in an analysis which also adjusted for socioeconomic status, maternal height and parity (Fall et al., 2015). Moreover, the setting of Ghana in Africa produced similar results, children of teenage mothers were more prone to be stunted, wasted and underweight (Wemakor et al., 2018). Hence, the authors concluded that the risk of child malnutrition decreases with an increase in maternal age. The relationship between young maternal age and child undernutrition could be a result of biological, behavioural, and social factors (Wemakor et al., 2018). For instance, it may be challenging for teenage mother to fulfil her own nutritional needs and the competing nutritional needs of the foetus compared to an adult mother (Wemakor et al., 2018; Wu et al., 2004). As a result of this, teenage mothers are likely to have a short breastfeeding duration compared to older mothers and may experience psychological stress (Wambach and Cole, 2000). These factors may increase the risk of malnutrition and lead to child stunting, wasting and underweight.

The educational status of the mother also has been established as an important determinant for the maternal role in child health (Caldwell, 1979; Desai and Alva, 1998a; Elo, 1992; Målqvist et al., 2012). Caldwell (1979) found that the children of educated mothers experience lower mortality than the children of uneducated mothers. Hence, the mother's education was identified as a precursor to improving child health (Desai and Alva, 1998a). It has been found that investments in women's education are important for lowering infant and child mortality and improving child health (Desai and Alva, 1998a; Summers, 1993). The strong relationship between maternal education and the improvement of child nutrition is well documented by many studies, and this may be because it is a proxy for socioeconomic status (Abuya et al., 2012; Desai and Alva, 1998a; Mary and Abhishek, 2015). Maternal education leads to improve earnings of the women which boosts household income and also maternal education positively correlates with increases in the nutritional status of the child in studies in various settings including Asian and African countries (Abalo et al., 2014; Hangoma et al., 2017; Makoka and Masibo, 2015; Panigrahi and Das, 2014). Thus, female illiteracy, poverty and lack of empowerment of women are major obstacles to improve maternal nutrition in these countries (Bhutta et al., 2004). In addition, maternal education caused a delay in age at marriage, childbearing and longer birth intervals which are also associated with a lower prevalence of child undernutrition. However, some studies have argued that maternal education is not good proxy for socioeconomic status, it may be mediated by social environmental, behavioural and residential factor (Desai and Alva, 1998a; Summers, 1993).

Further, it is revealed that maternal employment status is recognised as a double-edged sword in the LMIC context, as it can have both favourable and unfavourable consequences on child health outcomes. For instance, being employed, a mother would be able to increase overall household income, but this may also reduce the time allocation for caretaking activities such as breastfeeding (Popkin and Solon, 1976). Therefore, maternal employment presents a trade-off between potential income that could be produced to increase food availability and the unpaid work of mothers who are engaged in breastfeeding, child caring and cooking and cleaning (Nair et al., 2014) . An educated and employed mother has an increased decision-making ability regarding mobility and expenditure on health care (Hossain, 2013; Hosseinpoor et al., 2016; Vlassoff, 1994). This is found true for many studies conducted in LMICs where a large proportion of work occurs in the informal sector. Studies also investigated the possibility that maternal employment is associated with child obesity, as these children of employed mothers are likely to have sedentary behaviour and poorer eating habits (Fitzsimons and Pongiglione, 2018). The situation could be clearly recognised in the context of the nutrition transition, as maternal employment enables the family to afford energy-dense, processed foods (Oddo et al., 2018). However, the increased prevalence of obesity among the children of employed mothers is found to be particularly exaggerated for those working in the private sector, which may be indicative of both reduced time allocation to childcare activities and higher household income (Collins et al., 2008). It should be said, finally, that some cross-sectional studies conducted in Africa and Peru have found that there was no statistically significant association between maternal employment and nutritional status of their children (Chávez-Zárate et al., 2019; Eshete et al., 2017).

2.10.3 Household factors

Household wealth has repeatedly proven to be a crucial factor in predicting child nutritional status and child linear growth in numerous settings. The relationship is well investigated in the LMICs setting, particularly in Asia and Africa. As households' earnings strengthen, there is an increase in food security, access to various nutritious foods, and access to high-quality health care treatments for diseases which could contribute to the prevention of malnutrition (Greffeuille et al., 2016). Studies in various settings have discussed how poor household wealth affected child undernutrition. For example, a study conducted using 47 DHSs: twenty-six in sub-Saharan Africa, seven in the eastern Mediterranean, five in the south and south-east Asia, and nine in Latin America and the Caribbean. This study investigated a set of household assets and living conditions and found that poor nutritional status disproportionately affected the poor in all countries, including the regions of sub-Saharan Africa, eastern Mediterranean, south and south-east Asia, Latin America and the Caribbean (Van de Poel *et al*., 2008). In terms of the relationship between household wealth and prevalence of overweight, Black *et al*. (2013) found that the prevalence of overweight was approximately 1.31 times higher in children from the richest households, compared to those from the poorest.

In addition to wealth, the other household factors frequently found to be associated with child undernutrition outcomes are WASH (water, sanitation and hygiene) facilities such as access to clean drinking water, a sanitary latrine or toilet (van Cooten et al., 2019); and other factors such as the use of traditional or modern cooking fuel and availability of livestock. These factors often highlighted as intermediate factors for child undernutrition, are investigated in the settings of LMICs. A study emphasised how WASH interventions could combat nutritional challenges in Asia and sub-Saharan Africa by proving universal access to these services (Cumming and Cairncross, 2016). This study highlighted that adequate access to WASH facilities could reduce the incidence of infections that may be reflected in the reduction of undernutrition.

2.10.4 Community factors

Significant socioeconomic inequalities in stunting and underweight observed in both urban and rural areas are well documented (Almasian Kia et al., 2017; Memirie et al., 2016). A study conducted using 15 countries in sub-Saharan Africa found that socioeconomic inequalities in stunting existed in both urban and rural areas across the countries but that, these inequalities were significantly larger in urban areas. According to the study, intra-urban differences in child malnutrition are larger than overall urban-rural differentials in child malnutrition (Fotso, 2006). Abalo *et al*. (2014) argue that the prevalence of inequalities in maternal and child health services favours wealthy urban women, whereas rural women are less likely to receive sufficient maternal health care services. Inequality by wealth and rural-urban residence decreased over time in countries making progress in widening maternal health services, but this was not the case in countries that made insufficient progress in child and maternal health services (Alam et al., 2015). Therefore, it is suggested that policies should focus on the equitable distribution of basic social services (for example, water, sanitation, nutrition, adequate health, education, food security) and the provision and financing of these services are crucial for equality in the distribution of these health services (Omilola, 2010).

Further nutrition literature has paid growing attention to the use of random effects models to assess the impact of individual, household and community factors on children's nutritional status. This is often complementary to data which is collected in a hierarchical manner, such as

DHS data, which allows models to pay attention to how individual, household and community level factors explain the variation in child undernutrition outcomes. A study conducted using DHS data from numerous setting in Africa and multilevel logistic regression models reported that maternal community education is a strong predictor for child nutrition even after controlling for other variables (Abuya et al., 2012). For instance, community education could influence child undernutrition through many pathways. Living in a neighbourhood, an educated mother in a generally well-educated community could transfer knowledge on child nutrition, proper feeding and care practices for other mothers in her community. On the other hand, in a community with a high concentration of wealthier households, using health facilities becomes standard, so other women living in the same community, but in poorer households also may follow them. This could lead to generally better health service utilisation in the community.

Chapter 3 Methodology

3.1 Overview of Sri Lanka Demographic and Health Survey (SLDHS)

This research uses the Sri Lanka Demographic and Health Survey (SLDHS) conducted in 2016, throughout each of the three papers. This section describes the data and methods used in the study. The SLDHS is a national population and health survey conducted every 10 years with the aim of providing updated and reliable data useful to the policy planners in the Ministry of Health and other relevant institutions and researchers. SLDHS 2016 was momentous as it covered the entire island for the first time after the civil conflict ended in 2009. Further, SLDHS has employed the computer-assisted personal interview (CAPI) method for the first time in the history of the DHS in Sri Lanka.

3.2 Sample design

The 2016 SLDHS used a two-stage stratified sampling design. At the first stage, 2,500 census blocks were selected as primary sampling units (PSUs). At the second stage, 12 housing units were selected from each selected PSU as the secondary sampling unit (SSU). A census block is a subdivision of a Grama Niladhari Division, which consists of about 150 building units. The census frame covers about 65,000 census blocks. The sampling frame consisted of census blocks that were prepared for the Census of Population and Housing 2012.

A total sample of 2,500 Census Blocks (PSUs) was allocated by districts and then by urban, rural and estate sectors using the proportional allocation method with some adjustments considering the proportion of eligible respondents by each district. To ensure that each household was listed separately, a list of households was updated. In the selected PSUs, a fixed number of households was selected based on equal probability systematic sampling. Thereafter, a household questionnaire was completed from the list of residents and visitors who stayed at the household, night before the day of the interview. Since the main respondents of the survey are women, it was decided to identify ever-married women as eligible for the interview and every eligible woman was interviewed using an individual questionnaire.

A total sample of 28,720 housing units was selected for the survey and only 27,210 households were enumerated to provide district- level estimates. Information was collected from all ever-married women in the reproductive ages (15-49 years) about their children born after 2011. A total of 18,510 married women were identified as eligible (aged 15-49 years) and among them, 18,302 were successfully interviewed. The household response rate was 99.1 per cent (the rural sector had a higher response rate than urban and estate sectors) while the response rate of the eligible women was reported as 98.9 per cent. From these women, information was collected on the anthropometry of 8,104 children aged 0-59 months as well as on infant feeding practices, breastfeeding, vaccinations, nutritional status of mothers and children, succeeding and preceding birth intervals, childhood illnesses and mortality and use of maternal and child health services. We used the child recode dataset for the analysis of present interrelated papers.

3.3 Comparing the Sri Lanka DHS (SLDHS) to DHSs in other countries

It is useful to compare the structure of the Sri Lanka Demographic Health survey with the DHS programmes in other countries. The Demographic and Health Surveys (DHS) are nationally representative household surveys conducted by MEASURE DHS and funded by the United States Agency for International Development (USAID). Demographic and Health Surveys are normally designed to collect data on fertility and determinants of fertility, family planning, fertility preferences, infant and child mortality, reproductive health, nutrition, anthropometric measurements and HIV/AIDS-related knowledge and attitudes.

The DHS in Sri Lanka has not used the standard DHS format and it is not a part of the official Demographic and Health Survey. Unlike the other official DHS surveys, the Department for International Development (DFID) of the United Nations Population Fund (UNFPA) did provide financial assistance for the current survey. Technical assistance for the survey was provided by ICF International in the United States. The Sri Lanka Demographic and Health Survey (SLDHS) was carried out by the Department of Census and Statistics (DC&S) with financial assistance from the Ministry of Health, Nutrition and Indigenous Medicine in collaboration with the World Bank. The SLDHS has very similar components to the standard DHS, it used a similar methodology and incorporated recommended standard questions from conventional DHSs as much as possible. Apart from collecting information on the above-mentioned areas, SLDHS 2016 has widened to collect information on new areas such as mental health, awareness of well-women clinics, children who need special care and domestic violence. Information on topics which are highly applicable to the country such as malaria, use of mosquito nets, empowerment of women, use of alcohol and narcotic drugs and some non-communicable diseases were also collected in 2016 SLDHS. These variables are named in a way different from the regular DHSs, which complicates cross-country comparisons between Sri Lanka and countries taking part in the MEASURE DHS programme.

Generally, data sets from the DHS surveys are made available online through a process of electronic registration. SLDHS data are not in the public domain and are restricted for research use. Hence, essential ethical formalities were completed to get access to the data. First, ethical approval was granted by the Department of Census and Statistics, Colombo Sri Lanka. The approval complied with the data dissemination policy published by the Department of Census and Statistics in Sri Lanka. Ethical approval was also granted from the University of Southampton Faculty Ethics Committee under the Submission ID 42179.

After receiving ethical approval, datasets were sent through CSV (Comma-separated values format), which was later converted into the appropriate statistical software. There were five files named as persons, households, women, children and kids and file merging was done by using appropriate case identifiers. Initial exploration of the data was carried out to identify variables and since the variables are described with different names, DHS recode manual was not used to identify the variables. Survey weights were used to make the sample data representative of the entire population.

3.4 Variables used in the study

3.4.1 Dependent variables

This analysis was based on data from the 2016-2017 DHS in Sri Lanka, which collected information from a nationally representative two-stage clustered sample of 27210 household units covered in all districts of Sri Lanka. From these 27210 households, 18302 ever-married women, aged 15-49 were successfully interviewed to collect information related to childbirth and reproductive health. The majority of the women were currently married 16545 (90.4 per cent) and among them, 7,693 women had a birth during the last 0-59 months.

As dependent variables, the three inter-related studies which make up this thesis uses data on birth weight, nutritional outcomes such as height-for-age, weight-for-height and weight-for-age *z*-scores for children aged under five years (generated by the author) based on World Health Organization 2016 growth standards, and maternal body mass index (BMI).

SLDHS followed international standards in the definition of child and maternal anthropometric indicators. Stunting or a low height-for-age *z*-score (HAZ) is a measure of linear growth retardation and cumulative growth deficits. Children whose height-for-age are below minus two standard deviations (-2SD) from the median of the reference population are considered short for their age (*stunted*, or “of short stature” or characterised by linear growth retardation), which is an indicator that they are chronically undernourished. Children whose height-for-age is below minus three standard deviations from the median of the reference population are *severely stunted* (Department of Census and Statistics, 2017; Gorstein et al., 1994; World Health Organization, 2006).

Wasting or a low weight-for-height *z*-score (WHZ) measures body mass in relation to body height. Children whose weight-for-height are below minus two standard deviations (-2SD) from the median of the reference population are considered thin (*wasted*) which is an indicator of more acute malnutrition. Children whose weight for height are below minus three standard deviations from the median of the reference population are considered to be *severely wasted*.

Underweight or low weight-for-age is known as a composite index of height-for-age and weight-for-height that accounts for both acute and chronic undernutrition (Department of Census and Statistics, 2017; World Health Organization, 2006). Children whose weight-for-age *z*-score (WAZ) is below minus two standard deviations (-2SD) from the median of the reference population are classified as *underweight*. Children whose weight-for-age *z*-score are below minus three standard deviations from the median of the reference population are considered *severely underweight*.

Children whose weight-for-height *z*-score is more than two standard deviations above the mean of the reference population (WHZ > (mean + 2SD) are *considered overweight. Children's* weight was measured using a lightweight bathroom-type scale with digital screens designed and manufactured under the protocols of the United Nations Children's Fund (UNICEF). Children who were aged more than 24 months were measured standing up, whilst younger children were measured by asking them to lie down on a board (Department of Census and Statistics, 2017).

Children birth weights were obtained from the child health records which are described in detail in Chapter 4.

Maternal BMI, as a maternal anthropometric measure is used in Chapter 6 to identify the double burden of malnutrition.

It has been debated whether the recommended body mass index (BMI) cut-off points can be applied for determining overweight and obesity in Asian population (Misra, 2015; WHO Expert Consultation, 2004). By reviewing the scientific evidence, it has been suggested that Asian populations are susceptible to health risks related to BMI including the increased percentage of body fat and health risks such as higher cardiovascular risk factors than do European populations. Thus, WHO consultation concluded that the proportion of Asian people who have a high risk of type 2 diabetes and cardiovascular disease are considered at higher risk even at a BMI lower-level cut-off point for overweight (25 kg/m^2). Mortality risks for the Asian population tend to increase at BMI ≥25.0 kg/m2, and hence the cut-off points for obesity should be redefined as BMI of 23.0-24.9 kg/m2 for overweight. However, it is suggested that using revised cut points could potentially influence the estimated burden of obesity-related metabolic disorders among South Asians, Chinese and Aboriginals (Razak et al., 2007).

Sri Lanka has been using cut-off values recommended by the WHO. According to a cross-sectional study conducted in the Southern province of Sri Lanka, observed cut-off values of BMI in the study were laid within the ranges of those described by the WHO for Asian populations (Rathnayake et al., 2013). However recent studies in Sri Lanka argued that present cut-offs values may not capture the true prevalence of obesity, since the body fat percentages tend to vary significantly by ethnicity and geography (Jayawardena and Hills, 2020; Rathnayake et al., 2013). These studies highlight the need for developing country-specific and ethnic-specific BMI cut-off points. Given the non-uniformity of BMI cut- off values and the unavailability of country - specific BMI cut-offs, the present study adheres to the standard BMI cut-offs recommended by the WHO.

Maternal BMI is defined as the mother’s weight in kilograms divided by the square of her height in metres (kg/m^2). A cut-off point of 18.5 is used to define thinness or acute undernutrition. A BMI of 25 or above usually indicates being overweight, and 30 or above indicates obesity (Department of Census and Statistics, 2017; World Health Organization, 1995).

3.4.2 Computation of key independent variables of interest

The selection of independent variables is based on the research questions and factors outlined in the conceptual framework described in each respective chapter. Most of the independent variables were either original variables available in the DHS data or simple recodes of those original variables. However, some of the variables were obtained after separate computation. These computed variables and other specific universal variables are described below.

1. Maternal height

Low pre-pregnancy body mass index (BMI) and short stature of women are often reported as risk factors for poor birth outcomes and child anthropometry. As evident from the literature, maternal height indicates chronic malnutrition in the early life of the mother, which can hinder the environment of the foetus and can have a robust effect on the size of the neonate (Bisai, 2010; Martorell, 1999). Several studies have defined maternal short stature, referring to a threshold height of less than 145 cm (<145cm) (Desai and Alva, 1998b; Khatun et al., 2019). However, this is context-specific, as maternal height can be diverse in various geographic or ethnic groups. For instance, on average, Asian mothers have shorter maternal height (India- 152 cm, Philippines- 150 cm) than those in African (158 cm) South American countries (Brazil- 156 cm) and European counties (Sweden 166.1 cm) (Addo et al., 2013). In this study, maternal stature or maternal height is specified both as continuous exposure (expressed in centimetres) and as a categorical exposure with cut-offs. This study adopted the following cut-offs: short (≤145 cm); average (145.1-155 cm); tall (155.1 cm). These cut - points were selected based on prior use in maternal anthropometric studies in Sri Lanka and other Asian countries (Kader and Perera, 2014; Subramanian et al., 2009).

Considering the significance of maternal height as an indicator of intergenerational linkage between maternal and child health, maternal height is included as a separate variable along with maternal BMI in the analysis chapters. Using only the body mass index (BMI) variable might constrain the relationship between maternal height and the outcome of interest.

2. Preceding birth interval

Preceding birth interval is defined as the number of months elapsed between the birth date of the index child and that of the preceding child. Calculation of birth interval in DHS is reported elsewhere (Croft et al., 2018). The importance of birth interval in determining child undernutrition outcomes is explained in Chapter 2, section 2.10.

Birth order and preceding birth interval are checked for possible correlation (collinearity) prior to including those in the regression models. Birth order and preceding birth interval are highly correlated, with a variance inflation factor (VIF) value >10 indicating multicollinearity. This suggests that birth interval and birth order explain much of the similar variability in child undernutrition outcomes. In order to overcome this issue, only the preceding birth interval variable has been used for the analysis. On the other hand, preceding birth interval is extremely important in the low fertility context in Sri Lanka. For instance, Sri Lanka has the lowest TFR of 2.1 compared to other South Asian members and the country has long remained with fertility at replacement level. Birth interval is regarded as a significant factor associated with fertility levels in Sri Lanka. On average, women of Sri Lanka have 53 months interval between births, which is longer compared to other South Asian countries (Department of Census and Statistics, 2017). However, short birth intervals could be observed among women who belong to the estate sector (Department of Census and Statistics, 2017). In the light of these, the preceding birth interval is constructed with four cut-off intervals including first birth (reference); less than 24 months; 24-47 months; 48 months or more. These categories follow the DHS recommendations.

3. Household wealth

The wealth index is an asset-based composite index of household wealth developed combining ownership of a wide range of assets, housing characteristics and water and sanitation facilities using a principal component analysis. Each asset is assigned a weight (factor score), the scores are ranked according to the total score of the household, and the sample is then categorised into five quintiles from lowest (1) to highest (5).

Many economists have suggested consumption expenditure as an appropriate measure of living standards in low- and middle-income countries (LMICs), while income is widely used in high-income settings, particularly in developed countries (Howe et al., 2012; Sheppard et al., 2009). Consumption expenditure is considered as a steadier measure than income, particularly in low-income settings. Thus, using an asset-based wealth-based index as a proxy for socio-economic status (SES) has been criticised in LMICs. The wealth index could be biased, not reflecting the nature and relationship of the component variables that can differ in various contexts (Howe et al., 2012; Poirier et al., 2020).

Nevertheless, there has been evidence from national and international studies that the wealth index is a valid and reliable proxy for consumption expenditure as a measure of SES, particularly in middle-income countries (as opposed to low-income countries) (Howe et al., 2012; Howe et al., 2009). Asset ownership is unlikely to change in response to the temporary income fluctuations, thus asset ownership can be used as a measure of a household's long-term economic situation in a manner similar to consumption expenditure.

In Sri Lanka's setting, the asset-based index may be biased, particularly in the urban sector, when capturing the social and economic stratification compared to the rural and estate sectors. Urban households are more likely to have improved household access to utilities, infrastructure facilities and houses constructed of modern materials and conditions than are rural or estate households. On the other hand, rural and estate households may also possess agriculture or other land and livestock that are not included when constructing the wealth index. However, in the Sri Lanka Demographic and Health Survey (SLDHS) 2016-2017 a question on ownership of livestock has been included to help measure rural wealth scores.

Some studies have suggested constructing a separate wealth index for each residential sector or calculating wealth quintiles individually by type of area to avoid the observed misclassifications (Howe et al., 2008; Poirier et al., 2020). Some recent DHSs have included household wealth quintile variables generated specifically for urban and rural areas. Alas, the formation of such a specific wealth index for each sector was not possible with the SLDHS 2016-2017 data due to the unavailability of the weightings for each component. Therefore, the present study used the asset-based wealth index provided by DHS as the proxy for socioeconomic status. In this study, wealth index values were grouped into five quintiles: lowest, second, middle, fourth and highest (Department of Census and Statistics, 2017).

4 Maternal education

A mother's highest educational qualification was originally included as a continuous variable ranging from "never attended school" to "degree and above", considering each grade passed by the respondent at school. However, following the 2016 census definition in Sri Lanka, the variable was recoded into four groups as: (1) "up to grade 5"; (2) "grade 6 to GCE O/Level" (General Certificate of Education (GCE) Ordinary Level,); (3) "GCE A/Level" (General Certificate of Education Advanced Level and (4) "degree and above".

5 Ethnicity

The Sri Lanka DHS has seven categories reflecting the distinct ethnic groups in Sri Lanka such as Sinhalese, Sri Lankan Tamils, Indian Tamils, Sri Lankan Moors (Muslims), Malays, Burghers and others. However, the number of categories was reduced by recoding this variable into four main ethnicities. Malay, Burgher and other ethnicities represented only 0.6 per cent of the data sets on child health records and children aged under five years. Hence, this study considered combining Malay, Burgher and other ethnicities with the Muslim ethnicity and developed an ethnicity variable with four categories: (1) "Sinhalese"; (2) "Sri Lankan Tamils"; (3) "Indian Tamils"; (4) "Muslims, Malay, Burgher and other ethnicities". The ethnic classification is closely associated with religion, so a separate variable for religion was not considered necessary. For example, the population is 61 per cent Sinhalese and 64.6 per cent Buddhists. Since pretty well all the Sinhalese are Buddhist, Sinhalese comprise 94 per cent of the Buddhist population.

6 Provinces/regions

Sri Lanka is administratively divided into nine provinces: Western, Central, Southern, Uva, Northern, Eastern, North-western, North-central and Sabaragamuwa.

7 Infant and young child feeding practices

Four separate variables were created corresponding to the infant and young child feeding practice indicators in Chapter 5: "exclusive breastfeeding", "minimum dietary diversity", "minimum meal frequency" and "consumption of iron-rich foods". These were based on the indicators as specified by the WHO (2010).

8 Breastfeeding and complementary feeding for children (children living with their mother born 0 to 23 months before the survey)

We consider the percentage distribution of children exclusively breastfeeding, or breastfeeding and consuming plain water only, non-milk liquids, consuming other milk, and consuming complementary foods as an indicator of breastfeeding and complementary feeding during the 24 hours before the survey. This is examined for the youngest children aged under two years who live with their mothers.

Exclusive breastfeeding is defined as the proportion of children aged 0-6 months who were fed exclusively with breast milk in the day prior to interview (World Health Organization, 2018b). This variable was calculated using the numerator: infants aged 0-6 months who were fed only breast milk during the previous day, and the denominator was all infants aged 0-6 months.

9 Minimum dietary diversity (6-23 months)

This was defined for children aged 6-23 months. This variable was developed from the diet diversity score based on the proportion of children who received foods from four or more of the seven defined food groups: 1) grains, roots and tubers, 2) legumes and nuts, 3) dairy products, 4) flesh foods, 5) eggs, 6) vitamin A-rich fruit and vegetables and 7) other fruit and vegetables. The minimum dietary diversity was regarded as being achieved for breastfed and non-breastfed children if they consumed at least four of these seven food groups in the 24 hours prior to the interview.

10 Minimum meal frequency (6 -23 months)

This was defined as the proportion of breastfed and non-breastfed children aged 6-23 months who received a minimum frequency of solid, semi-solid, or soft foods (but also including milk feeds for non-breastfed children) in the 24 hours preceding the interview. The minimum was defined as: two times per day for breastfed infants age 6-8 months, three times per day for breastfed children aged 9-23 months, or four times per day for non-breastfed children aged 6-23 months.

11 Consumption of iron-rich foods (6-23 months)

This was defined as the proportion of children aged 6-23 months who received iron-rich food during the 24 hours preceding the interview, which includes meat, fish, poultry, and eggs.

12 Child immunisation (12-23 months and 12-59 months)

The association between immunisations status and children's undernutrition outcomes is examined in Chapter 5. Immunisation records of the child should be included in the child health data records (CHDR) given to the child's parents. The 2016 SLDHS collected information on child immunisation from the CHDR for all living children born during the five years prior to the survey. If the CHDR was not presented during the survey, the mother of the child was asked to recall whether the child had received each vaccine. According to the immunisation programme in Sri Lanka, to have received all basic immunisation the children should have been given a BCG injection soon after birth, three doses of immunisation against diphtheria, pertussis, tetanus, polio, hepatitis B and haemophilus influenza type B (at 2, 4 and 6 months) and are immunised against measles at 9 months. They receive a booster immunisation against diphtheria, pertussis and tetanus and polio at 18 months, and a booster measles injection at 3 years. Immunisation status was usually calculated for children who are aged 12–23 months and 24-35 months (Department of Census and Statistics, 2017).

This study calculated immunisation for living children aged between 12-24 months and 12-59 months who received immunisation at any time before the survey, according to either the CHDR immunisation card or the mother's report. Immunisation status was classified as "fully immunised" if the child received all basic immunisation; "partially immunised" if the child had missed any of the basic immunisation given under the national immunisation programme during the first year of life and "not immunised" if the child had received no immunisation.

3.5 Analytical methods

Data analysis was performed using Stata 15.0 (Stata Corp, College Station, TX, USA). 'Svy' commands were used to allow for adjustments in the cluster sampling design.

3.5.1 Justification of using both linear and logistic regression models to examine birth weight (Chapter 4)

This study applied both multiple linear and multiple logistic regression models to investigate the effect of various factors on low birth weight. Both models are frequently used in quantitative health care research to examine the effect that various factors may have on some output variable of interest. For example, linear regression models can be applied to explore the factors that affect birth weight; however, logistic regression models will be used to predict the independent effect of factors associated with low birth weight.

Logistic regression models were based on the standard definition of low birth weight (LBW) (< 2,500 grams), which is a conventional cut-off point that can be used to categorise each baby as low birth weight or not. The binary nature of this variable will help in comparing other studies which used this standard cut-off point in their modelling methods. Further, multivariate logistic regression results are presented in odds ratios that are helpful to researchers, health care providers and policymakers for further designing of policies and interventions on low birth weight. However, with logistic regression models, comparing the values of odds ratios across models with different specifications is problematic (Mood, 2010).

On the other hand, using multivariate linear regression models also have some benefits. Birth weight as a binary variable can be problematic in terms of misclassification of birth weight of children in a population survey. There is heaping in reported birth weights on 2,500 grams exactly. Thus, even though birth weight recodes are taken from health recodes, it is likely that some babies whose reported birth weights were exactly 2,500 grams were less than 2,500 grams at birth and would therefore be misclassified (Channon, 2011). In linear regression, birth weight is used as a continuous outcome (weight in grams of a baby), which we assume that error terms are normally distributed. This allows valid comparison of coefficients across models with different specifications. Further, multiple linear regression shows the distribution of average birth weight. The difference between linear and logistic regression is the nature of the outcome variables and the assumptions underlying the models. Otherwise, the two methods follow the same principles and considerations (Bonellie, 2012).

3.5.2 Multiple linear regression model

In the multiple linear regression model, this study uses the outcome variable as the birth weight for the children who are aged 0-59 months at the time of the survey. The estimates (coefficients and constant) are used to construct a prediction equation and generate predicted scores on a variable for further analysis.

The equation estimated may be written as:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} + \varepsilon_i \tag{3.1}$$

where y_i is the birth weight in grams of child *i*, x_{1i} x_{pi} are the values for child *i* of the *p* predictor variables including maternal depletion factors and socioeconomic and geographic factors, $\beta_1 \ldots \beta_p$ are parameters to be estimated and ε_i is the random error for child *i*.

3.5.3 Binary logistic regression model (Chapters 4 and 5)

In order to identify the association between explanatory variables with outcomes of interest, bivariate analysis was conducted with a chi-square test of association. Binary logistic regression models are non-linear regression models, generally used to find the best fitting model to describe the relationship between a dichotomous characteristic of interest and a set of predictor variables (Long and Freese, 2001). This is an extension of using multiple regression analysis, in which the outcome variable is categorical with two possible values.

Logistic regression generates the coefficients of a formula to predict a logit transformation of the probability of the presence of the characteristic of interest. Let the logit transformation of the outcome be Z_i. The relationship between Z_i and multiple explanatory variables can be presented as follows:

$$Z_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_p x_{pi} \qquad (3.2)$$

where Z_i is the value of the dependent variable for individual *i*, $x_{1i} \ldots x_{pi}$ are the values of the *p* covariates for individual *i*, and $\beta_{0 \ldots\ldots} \beta_p$ are parameters to be estimated.

The dependent variable, Z_i, follows a logit link function, with a logit transformation of probability. Suppose we are interested in measuring the factors associated with the presence or absence of some characteristic.

Define a variable Y_i such that $Y_i = 1$ if the characteristic is present for individual *i*, and $Y_i = 0$ otherwise. Then we can write the model as:

$$log\ \frac{Pr[Y_i=1]}{Pr[Y_i=0]} = log\frac{Pr[Y_i=1]}{1-Pr[Y_i=1]} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} \qquad (3.3)$$

Which may be re-arranged to read:

$$\Pr[Y_i = 1] = \frac{\exp(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi})}{1 + \exp(\beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi})} \qquad (3.4)$$

where $\Pr[Y_i = 1]$ is the probability that the outcome of interest is present (for example the probability of a child being born with low birth weight or being stunted, wasted or underweight).

Estimates of the parameters $\beta_{0 \ldots\ldots} \beta_p$ of the model are obtained by the method of maximum likelihood; these estimates allow us to work out the probabilities (low birth weight in a given woman/ child undernutrition), substituting in the formula the values of $x_{1.....}\ x_p$ presented by the given woman/child.

In our case, it is the probability of having a low birth weight, or a stunted/wasted/underweight child divided by the probability of not having such an outcome. It can be shown with relative ease that $\exp(\beta_1)$ … exp(β_p) represent the *odds ratios* that allows the comparison of two categories of the corresponding explanatory variable p when the values of the other explanatory variables remain constant. Therefore, to compare categories of the explanatory variables the odds ratio is used. A reference category was defined for all categorical covariates in the study in order to interpret the odds ratios.

3.5.4 Multinomial logistic regression (Chapter 6)

Multinomial logistic regression is an extension of binary logistic regression. It models outcomes that have three or more categories which are not ordered (Hosmer and Lemeshow, 2015; O'Connell, 2006). The outcome variable of Chapter 6 has five responses which are: (1) “stunted children with underweight mothers”, (2) “stunted children with normal-weight mothers”, (3) “stunted children with overweight mothers”, (4) “stunted children with obese mothers”, (5) “non-stunted children with normal weight mothers”.

When modelling a polychotomous variable using multinomial logistic regression, the dependent variable is categorised into multiple dummy variables coded ‘1’ and ‘0’. However, not all categories are coded into dummy variables: one category is left to be named as a reference category. Thus, for a variable with *C* categories, *C* - 1 dummy variables are created and each category is compared with the reference category in a separate binary logistic regression model (Becg and Gray, 1984). Thus, the probability of success of each category is modelled in that category in comparison to the reference category (Hosmer and Lemeshow, 2015). In our case, we have four categories of the double burden of malnutrition at the household level (y_i = 1, 2, 3, 4) where non-stunted child/normal weight mother is the reference category (y_i = 0). The modelling probabilities are as follows (suppressing the subscripts *i* for clarity):

$$(y = 1|x) = \frac{\Pr[y = 1|x]}{\Pr[y=0|x]} = \beta_{10} + \beta_{11}x_1 + \beta_{12}x_2 + \cdots + \beta_{1p}x_p \qquad (3.5)$$

$$(y = 2|x) = \frac{\Pr[y = 2|x]}{\Pr[y=0|x]} = \beta_{20} + \beta_{21}x_1 + \beta_{22}x_2 + \cdots + \beta_{2p}x_p \qquad (3.6)$$

$$(y = 3|x) = \frac{\Pr[y = 3|x]}{\Pr[y=0|x]} = \beta_{30} + \beta_{31}x_1 + \beta_{32}x_2 + \cdots + \beta_{3p}x_p \qquad (3.7)$$

$$(y = 4|x) = \frac{\Pr[y = 4|x]}{\Pr[y=0|x]} = \beta_{40} + \beta_{41}x_1 + \beta_{42}x_2 + \cdots + \beta_{4p}x_p \qquad (3.8)$$

where x_1, x_2, … x_p are the covariates and β_{10}, …, β_{1p}, β_{20}, …, β_{2p}, β_{30}, …, β_{3p}, and β_{40}, …, β_{4p} are parameters to be estimated.

The output of the multinomial regression can be defined in two ways, using odds ratios (relative risk) or probabilities. A probability is "the ratio between a number of events favourable to some outcome variable divided by a total number of events"(Sperandei, 2014, p. 14). The relative risk (also referred to as the odds), is the ratio of the probability of choosing a specific other outcome category over the probability of choosing the baseline category.

In the binary logistic regression model with two outcome categories (y = 1 and y = 0), with y = 0 as the baseline category, then the odds is $\frac{\Pr[y=1|x]}{1-\Pr[y=1|x]} = \frac{\Pr[y=1|x]}{\Pr[y=0|x]}$. For the multinomial model, however, odds computed as $\frac{\Pr[y=1|x]}{1-\Pr[y=1|x]}, \frac{\Pr[y=2|x]}{1-\Pr[y=2|x]}$, and so on are not comparable as, generally

$1 - \Pr[y = 1|x] \neq 1 - \Pr[y = 2|x]$, etc. Relative risks can still be estimated by exponentiating the regression coefficients that are relative risk ratios for a unit change in the predictor variable. When a relative risk ratio is greater than 1, it suggests an increased risk of that outcome in the exposed group, while if it is less than it indicates a reduced risk in the exposed group. In order to understand further effect between the explanatory variables and the likelihood of each outcome, predicted probabilities are also presented and some of the predicted probabilities are graphically represented.

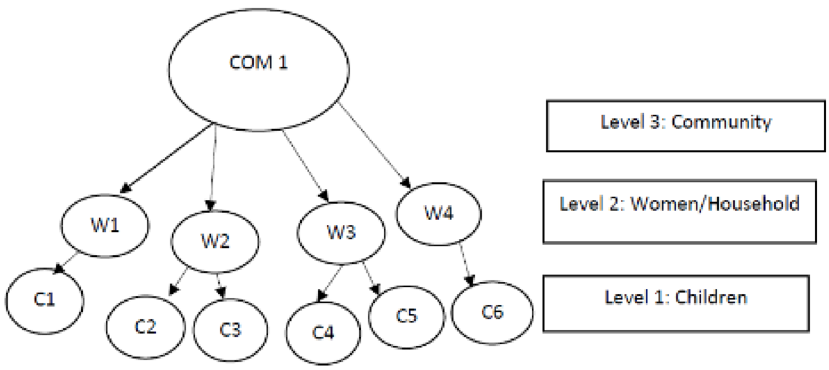
3.5.5 Multilevel logistic regression models (Chapters 4 and 5)

Due to the hierarchical nature of the Demographic and Health Survey (DHS) data, this study uses a multilevel logistic modelling approach to analyse the factors associated with low birth weight and child undernutrition outcomes. Multilevel modelling generates robust estimates when observations are clustered so that the error terms are correlated. For example, children born to the same mother might be expected to be more similar on unobserved factors than children born to different mothers.

3.6 Multilevel models

Multilevel models consider the variation between both individuals and the higher-level clusters in which individuals are nested. The DHS data use a four-level hierarchy. Children are nested within mothers; mothers are nested within households; and households are nested within communities. However, to include all four levels in the same model is not feasible with the data. One reason for this is that the vast majority of households contain only one mother, so that in practice the mother and the household levels can be regarded as the same (as demonstrate this below). Taking this into account, this study considered a three-level random intercept logistic regression model to estimate how the birth weight of the individuals (children) was associated with mothers/households nested in clusters (Figure 3.1). At the community level, the primary sampling units (PSUs) of the DHS were identified as clusters, used as the proxy for capturing community effects.

Figure 3.1 Multilevel structure of the study



3.6.1 Multilevel logistic regression

Multilevel logistic regression, as used here, is an extension of logistic regression to include random intercepts. We start with a three-level null or intercept-only model (that is, a model without covariates) in which children (individuals) (denoted i), simultaneously belong to the mother/household (denoted *j*) nested into the clusters (denoted *k*). If π_{ijk} is the probability that child *i* of mother *j* in cluster *k* is of low birth weight, we write:

$$\log_e\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = \beta_0 + \eta_k + \mu_{jk} \tag{3.9}$$

On the left-hand side of this equation is the log-odds of a child being of low birth weight. This is modelled as the sum of three parameters. β_0 is the intercept, which is the average value of the log-odds, but this log odds is allowed to vary by cluster and by mother/household. The variations by cluster and mother/household are expressed as deviations from β_0 and written as η_k and μ_{jk} respectively. This model is sometimes called a *variance components model*.

If we wish to add individual-level covariates to this model, we can do so as follows:

$$\log_e\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = \beta_0 + \beta_1 x_{1ijk} + \ldots + \beta_q x_{qijk} + \eta_k + \mu_{jk} \tag{3.10}$$

where $\beta_1 \ldots \beta_q$ are parameters to be estimated, and $x_{1ijk} \ldots x_{qijk}$ are the covariates.

Random effects for the maternal, household and community level were assessed by using the intra-class correlation coefficient (ICC), which measures the proportion of variance in the outcome attributable to clustering at each level. ICC is a measure which quantifies the degree of homogeneity of the outcome (i.e stunting) within cluster(s). If the ICC =0, it presents greater homogeneity, that means perfect independence of residuals; the observation does not depend of cluster membership. If the ICC=1, then it presents perfect interdependence of residuals. This means that the observations only vary between clusters (Sommet and Morselli, 2017).

The ICC for two-level binary data was calculated using the following formula

$$\text{ICC}=\frac{\sigma_b^2}{\sigma_b^2 + (\pi^2/3)} \quad (3.11)$$

The ICC was calculated using the formula above, in which is σ_b^2 the random intercept variance, that is, the level-2 variance component and the term $(\pi^2/3)$ is associated with the logistic distribution. Similar formulae were used for the mother/household level and the individual level.

3.7 Assessment of model fit

For each respective analysis, independent variables with a significant Wald chi-squared test statistic ($p < 0.05$) in univariate analysis, were included in the final multivariable linear/logistic models. In the model building, explanatory variables were entered simultaneously in the models and variables that did not meet the required 5 per cent level of significance were excluded. However, some variable like household wealth that was deemed to be theoretically important was retained in the final model despite insignificant test statistics. Furthermore, variables that had been excluded on the basis of insignificant (> 0.05) P-values in bivariate analysis were entered individually into the logistic regression model to check any change in model estimates.

The results of the multivariate linear regression models are presented as coefficients and standard errors of coefficients while the results of the logistic regression analyses are reported in the form of odds ratios (ORs) with 95 per cent confidence intervals (CIs). For Chapter 6, results are described as relative risk ratios (RRR) with 95 per cent confidence intervals (CIs).

The selection of the most parsimonious models was carried out using the Hosmer-Lemeshow goodness of fit test. The collinearity between explanatory variables was assessed using the estimated variance inflation factors (VIFs), for which values below 10 were considered to be acceptable in the final models. The receiver operating characteristic curve (ROC curve) was employed to examine the predictive ability of the logistic regression models. In addition, for the multinomial logistic regression models, STATA “fitstat” command was used to obtain a variety of fit statistics.

For the multilevel logistic regression, parameters were estimated using “xtmelogit” command in STATA. Model fit statistics such as Akaike’s information criterion (AIC) and Schwarz’s Bayesian information criteria (BIC) were used to assess goodness of fit and report the selection of nested models (individual-household-community-level model). The model with the lowest values of these criteria was considered to be the best-fit model (Merlo *et al.*, 2006).

3.8 Measures of inequality

Studies at the global level sequentially identified socioeconomic inequalities in a range of health outcomes including premature mortality, cardiovascular disease, obesity, diabetes and self-reported ill health among different socioeconomic groups (Matthews, 2015; Murray et al., 1999; World Health Organization, 2007). Health inequalities reflect comparative analysis of the determinants of health, ranging from best to the worst of individuals within the range (Murray et al., 1999). A few studies in Sri Lanka have examined socioeconomic inequalities in child malnutrition, which were mainly concentrated among households with low socioeconomic status. Moreover, these studies were not conducted at the national level, or even in post-conflict Sri Lanka (Jayasinghe, 2010; Jayawardena, 2014; Rannan-Eliya et al., 2013).

This study will measure socioeconomic inequality in the prevalence of low birth weight and child undernutrition using concentration indices and curves. The concentration index is a well-known complex health inequality measure, which explains health gradients across multiple subgroups within the social hierarchy (World Health Organization, 2007, 2015b). It is defined as twice the area between the concentration curve and the line of equality (the 45-degree line) (O'Donnell et al., 2016; Zhang and Wang, 2007).

Concentration index can be expressed as

$$\boldsymbol{CI} = \frac{2}{\mu}\, \boldsymbol{cov_w}(\boldsymbol{h_i r_i}) \qquad (3.12)$$

where h_i is the health variable across which inequality is measured μ its mean and r the fractional rank by income (i.e $r_i = i/N$ is the fractional rank of individual i in the living standards distribution, with $i = 1$ for the poorest and $i = N$ for the richest person) (O'Donnell *et al*., 2016).

To calculate the CI, a CC must first be constructed. To construct the CC, the study population is ranked by a socioeconomic variable such as income. The ranking of income is then plotted against a health variable of interest. On the x-axis, the population is plotted, cumulatively ranked from least socioeconomically poorest on the left to the richest on the right. The y-axis presents the cumulative proportion of the health variable of interest associated with a given rank in SES on the x-axis (Huda et al., 2018; Kakwani et al., 1997; Mohammad et al., 2016; O'Donnell et al., 2016).

The values of the CI can vary between -1 and 1, where negative values represent the fact that the concentration curve lies above the line of equality, indicating the disproportionate concentration of the health variable among the poor population (pro-poor inequality). The positive values plot below the line of equality (pro-rich inequality) and zero values represent as perfect equality (Mohammad et al., 2016; O'Donnell et al., 2016; Zhang and Wang, 2007).

The concentration curve is a pictorial view of the pattern and magnitude of inequalities in health (Novignon et al., 2015). Consider the example of child malnutrition and the wealth index. In this case, the curve would be a plot of the cumulative percentage of child malnutrition on the *y*-axis and the cumulative percentage of the population ranked by wealth index on the *x*-axis (O'Donnell *et al.*, 2016). If the concentration curve lies on the 45° line, this shows perfect equality in terms of child nutrition irrespective of wealth status. When the curve lies below the line, child malnutrition is concentrated on the rich population with higher socioeconomic status (SES). If the curve lies above the line, the outcome is more concentrated among the lower SES individuals in the population (Novignon et al., 2015; O'Donnell et al., 2016). The magnitude of the inequality is represented by the distance between the curve and the line of perfect equality. For example, in the child malnutrition case, if the magnitude of inequality in favour of rich people was very high (child malnutrition being heavily concentrated among the poor), the curve would be well above the line of equality.

Studies have addressed some advantages and limitations of CI. Some advantages of using CI have been also reported; CI results are not likely to be biased depending on the sample size. CIs are also sensitive to changes according to the socioeconomic distribution.

Despite widely used by studies in health economics, there are some growing concerns on the applicability of CI, in terms of measuring health inequalities. For instance, Erreygers (2009) argued that the value or the bounds of the CI (–1 and +1) depends on the mean of the health variable, which is being explored as binary in nature (value of 0 or the value of 1) (Erreygers, 2009).Thus, if the mean increases (i.e closer to 1), the values of the CI tend to shrink or if the population has a low mean, CI value can be wider (Erreygers, 2009). Therefore, it has been suggested that comparing populations with different mean health levels using CI should be done carefully. Nevertheless, the applicability of corrected CI is also limited, depending on the nature of the health (outcome) variable (Erreygers, 2009).

Another limitation of CI is that it can be applied, if there is a strict ranking of socioeconomic variable such as income, also missing income data can be biased the value of CI (Zhang and Wang, 2007). However, this limitation cannot be applied to the present study, as data on income variable were available for respondents, therefore the effect of the bias to be minimal for each health variable of interest.

In terms of representativeness, the Sri Lanka DHS recorded a 99.1 per cent household response while yielding a 98.9 per cent for the eligible women who participated in the survey. Missing data on independent variables was minimal (less than 2 per cent), therefore it was treated as missing at random and included in the bivariate and multivariate analysis. Missing cases for the outcome variable were reported in each chapter. In Chapter 4, a separate missing data analysis is done and presented by residential and wealth quintiles to identify any anomalies. However, missing values were not substantial.

Chapter 4 Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and Health Survey 2016

4.1 Abstract

Background: Low birth weight (LBW) is a major public health concern in Sri Lanka as the percentage of children born with LBW has remained at around 17% since the year 2000.

Aim: To investigate social inequalities underlying low birth weight (LBW) outcomes in Sri Lanka.

Methods: This study used the DHS-2016 data, the first survey covered the entire country after the war ended in 2009. We applied both multivariate and multilevel logistic regression models to examine the association between LBW and maternal, socioeconomic and geographic variables. Concentration indices were estimated for different population subgroups. We hypothesised that children born in the estate sector living in poor households have higher risks of undernutrition than their counterparts in other sectors.

Participants: Birth weight data extracted from the child health development records available for 7713 babies born between January 2011 and the date of interview in 2016. Outcome measures. The main outcome variable was birth weight, classified as LBW (≤2500 g) and normal.

Results: The population-level prevalence of LBW was 16.9% but was significantly higher in the estate sector (28.4%) compared with rural (16.6%) and urban (13.6%) areas. Negative concentration indices suggest a relatively higher concentration of LBW in poor households in rural areas and the estate sector. Results from fixed - effects logistic regression models confirmed our hypothesis of significantly higher risk of LBW outcomes across poorer households and Indian Tamil communities. Results from random intercept models confirmed there was substantial unobserved variation in LBW outcomes at the mother level. The effect of maternal biological variables was larger than that of socioeconomic factors.

Conclusion: LBW rates are significantly higher among babies born in poorer households and Indian Tamil communities. The findings highlight the need for nutrition interventions targeting pregnant women of Indian Tamil ethnicity and those living in economically deprived households.

Key messages

- Low birth weight rates are highest among Indian Tamil communities living in the estate sector and who are living in the poorer households.
- The effect of maternal biological variables is larger than that of socioeconomic factors.
- Nutrition interventions should be targeted on women belong to the Indian Tamils ethnicity and live in poor households.

4.2 Introduction

Although Sri Lanka's child mortality rates have declined substantially, indicators related to children's health and nutrition have showed shown little or no progress for two decades. The percentage of children born with low birth weight has remained stagnantly high and represents a critical public health problem in Sri Lanka. This chapter investigates how low birth weight is distributed among different socioeconomic groups and across the residential sector and geographical provinces. It also examines the role of maternal depletion and socioeconomic factors associated with low birth weight in Sri Lanka. This chapter will first present the relevant national and international literature and discuss the range of bio-behavioural and socioeconomic factors associated with birth weight. Then it presents the bivariate analysis of low birth weight and associated factors at the child, maternal, household and geographic levels. The extent of inequalities in low birth weight, their distribution across different socioeconomic groups and community sectors is illustrated in the next section. Then it compares different modelling approaches with a multilevel approach to examine the maternal, household and community effect on low birth weight.

4.3 Low birth weight: an overview

Low birth weight (LBW), defined as a newborn with a weight below 2500 grams, remains a significant global health concern (World Health Organization, 2006, 2014a). Reducing the prevalence of low birth weight contributes to the health-related goals within the Millennium Development Goals (MDG) for reducing child mortality and the Sustainable Development Goals (SDGs) (Khan et al., 2018; World Health Organization, 2014a).

Overall, it is estimated that 20 per cent of all births annually are low birth weight newborns (World Health Organization, 2014a). Global and regional variations in LBW rates are pronounced: low and-middle-income countries represent the highest burden of LBW; more than 95 per cent of the global LBW infants are born in low and middle-income countries. This is specifically the case in South Asia, which has the largest prevalence (28 per cent) of LBW babies (Mahumud et al., 2017; World Health Organization, 2014a). Among the countries in South Asia, Bangladesh, Indian and Pakistani women tend to have the highest rates of low birth weight babies (Leon and Moser, 2012). It is estimated that Sub Saharan Africa has the second largest share of 13 per cent, while East and Pacific Asia has the lowest low birth weight rates at 6 per cent (World Health Organization, 2014a). Monitoring the prevalence of LBW in LMICs is more challenging because more than half of infants in the LMICs are not weighed. Population-based surveys in these countries often rely on statistical methods to adjust for the underreporting and misreporting of birth weights. This may lead to an underestimation of the prevalence of low birth weight in LMICs (Ramakrishnan, 2004).

The consequences of low birth weights are not restricted to the individual alone, but to the society as a whole. LBW is one of the major contributors to high infant and under-five mortality rates in developing countries (Mahumud et al., 2017). Children born with LBW may experience both long-term and short-term adverse consequences including higher probabilities of infection, malnutrition and cognitive disabilities during childhood (including cerebral palsy); mental deficiencies; and problems related to behaviour and learning (Hack et al., 1995; Khan et al., 2016; Kramer, 1987; Negrato and Gomes, 2013). Children who survive with LBW are susceptible to the high incidence of diseases, retardation in cognitive development and increased adulthood risks of non-communicable diseases (NCD) when compared to normal birth weight children (Barker, 2001; Barker, 2012; Fall, 2013; Sivasankaran and Thankappan, 2013).

A number of studies at the global level have acknowledged that the contributing factors for LBW are multifaceted. Maternal factors encompass maternal age, poor maternal nutritional status, Body Mass Index (BMI), gestational age, intervals between pregnancies, parity, lack of antenatal care (ANC) and other socioeconomic and environmental factors particularly related to low socioeconomic status (Kader and Perera, 2014; Mahumud et al., 2017).

4.4 Bio - behavioural and socioeconomic factors associated with low birth weight

4.4.1 Maternal depletion factors

This section presents a review of selected literature, with a focus on bio-behavioural and socioeconomic factors associated with low birth weight outcome. Adequate nutritional status during pregnancy plays a vital role in pregnancy outcomes (da Silva Lopes et al., 2017; Muthayya, 2009; Stephenson and Symonds, 2002). Maternal depletion is defined as a condition or a phenomenon where the nutritional status of the mother tends to deteriorate with increasing reproductive stress. Also, termed as Maternal Depletion Syndrome (MDS) means the weight loss among women who have either early or closely spaced pregnancies. However, Winkvist et al (1992) presented a novel approach in defining maternal depletion and suggested two hypotheses towards investigating MDS: i) women with high parity show a poor nutritional status compared to women with low parity ii) short intervals between childbirth (parturition) are associated with poor maternal health and poor pregnancy outcome (Winkvist et al., 1992). In general, maternal depletion can be interpreted as a negative effect of change in maternal nutritional status with a shorter period of potential repletion during the inter-pregnancy interval or having low nutritional reserves at the beginning of pregnancy. Hence, maternal depletion may contribute to increase the risk of having poor birth outcomes such as low birth weights and growth retardation (King, 2003). Poor pregnancy outcomes such as LBW in developing countries often.are blamed on maternal depletion, as there is a direct and indirect link between poverty and maternal nutrition. For instance, poor mothers often take poor diets, engage in heavy workloads and they are unlikely to access quality nutrition and maternal services such as the use of family planning methods. These mothers hence have increased frequencies of closely spaced pregnancies that could determine a negative effect on their nutrition (Miller and Huss-Ashmore, 1989).

The next section reviews some of the literature discussed on the factors that influence maternal depletion and maternal nutrition and how these factors are linked with poor birth outcomes, in particular, low birth weight.

There is well-established evidence on how the interpregnancy interval of a mother is associated with poor birth outcomes such as low birth weight (Hussaini et al., 2013; King, 2003; Merklinger-Gruchala et al., 2015). The interpregnancy interval was calculated as the time elapsed between the conception date of any second or higher order birth and the date of a prior birth (Gemmill and Lindberg, 2013; Mahumud et al., 2017). Interpregnancy intervals play a crucial role in determining the risk of delivering preterm, low birth weight or small for gestational age (SGA) outcomes (King, 2003). Short interpregnancy intervals can be defined as intervals of less than 18 months (Gemmill and Lindberg, 2013; King, 2003). Existing literature documents that young or adolescents' mothers with short interpregnancy intervals are more likely to have low birth weight babies and preterm deliveries when compared to adult mothers (Frisancho et al., 1983; Naeye, 1981). This was reported in the USA study, which highlighted that the risk of having low birth weight or preterm birth for adolescent mothers is at least 50 per cent greater than that of adult women with an interpregnancy interval of 18–59 months (Zhu et al., 2001). However, some scholars argue that the risk of having poor pregnancies due to short birth intervals is attributed to various factors including socioeconomic and maternal lifestyle-related factors (King, 2003; Stylianou-Riga et al., 2018).

Biological maturity and optimal weight gain during pregnancy are some of the concepts frequently highlighted in literature for the desirable foetal outcome (King, 2003). It was documented that teen mothers tend to give birth to smaller ones (Gibbs et al., 2012; King, 2003). A study in Thailand shows that mothers with inadequate maternal weight gain (< 5-9kg) of any BMI group during pregnancy had a 3.4 times greater risk of having low birth weight babies (Sananpanichkul and Rujirabanjerd, 2015). In contrast, evidence from a systematic review which synthesized findings from 84 studies showed that individuals who were overweight or obese had increased risks of both an induced preterm birth before 37 weeks and very or extremely low birth weight infants (McDonald et al., 2010).

Apart from the maternal BMI and nutritional status, advanced maternal age during the time of birth (defined as aged 35 years or above) is also associated with an increased risk of low birth weight (Bewley et al., 2005; Saloojee and Coovadia, 2015). This is demonstrated in both high and middle-income countries, where increasing numbers of women are giving birth over the age of 35.(Santos et al., 2008; Scholl et al., 1994). In contrast, it is argued that maternal age is not associated with the risk of low birth weight, hence there are unobserved maternal health, social and genetic factors that could be attributed to poor birth outcomes (Goisis et al., 2017).

The essentiality of consuming micronutrients during pregnancy for better maternal nutrition is widely acknowledged in the literature (Bigiu et al., 2015; Marangoni et al., 2016). Micronutrients are essential for healthy foetal development (Bigiu et al., 2015; Marangoni et al., 2016). The key micronutrients include iron and folic acid. Low consumption of these micronutrients during pregnancy may cause multiple negative effects on both maternal health and foetal development (Bigiu et al., 2015). It is suggested that both folic acid and iron supplements should be provided to pregnant mothers in order to reduce the risk of anaemia and infant morbidity and mortality rates (Iyengar and Rajalakshmi, 1975).

There is also evidence to support the premise that proper and adequate antenatal (ANC) visits have an influential effect on the likelihood of having a healthy baby (Kader and Perera, 2014). Access, quality, number of visits and gestational age at first prenatal visit are all statistically associated with normal birth weight outcomes (Carvalho Padilha et al., 2009; Pinzón-Rondón et al., 2015). However, in Brazil, research shows that socioeconomic factors tend to outweigh antenatal visit factors to predict low birth weight outcomes (da Fonseca et al., 2014).

4.4.2 Socioeconomic, household and geographic factors

Besides the influence of maternal factors on poor birth weight, a strong association between socioeconomic status (SES) and birth weight outcomes has been reported by many studies across different settings (Parker et al., 1994; Torres-Arreola et al., 2005). Being in the poorest social stratum significantly increases the risk of LBW – confirmed in 10 developing countries including Indonesia, Pakistan, Nepal and some African countries such as Tanzania and Uganda (Mahumud et al., 2017). Similar associations were reported in four developed countries such as the United States, the United Kingdom, Canada, and Australia. The differences in living conditions, low income and low education were associated with increased risk of LBW in all of these four countries (Martinson and Reichman, 2016). A study in Canada estimated that 30 per cent of low birth weight babies could be attributed to maternal poverty including lower levels of education and poor dietary habits (Larson, 2007). The association between maternal poverty and low birth weight was confirmed in an Irish study which concluded that low maternal income is a significant predictor of low birth weight babies (Madden, 2014).

Race and ethnicity were also found to be important predictors of low birth weight in different contexts (Barron, 1983; Fulda et al., 2014). People that share similar geographical, social, and cultural backgrounds are likely to have a minimum birth weight difference. This was witnessed among Indian, Pakistani and Bangladeshi infants born in the UK were 280–350 g lighter, and 2.5 times more likely to be low birth weight compared to White infants (Kelly et al., 2009).

Furthermore, spatial factors were more significant for US women, those in dense urban areas have the worst birth weight outcomes compared to rural mothers (Kent et al., 2013). However, studies have concluded that LBW is associated with rural residence due to the limited access to health care facilities in rural settings (Strutz et al., 2012; Yi et al., 2011). In addition, income deprivation has a negative effect on low birth weight (Dibben et al., 2006).

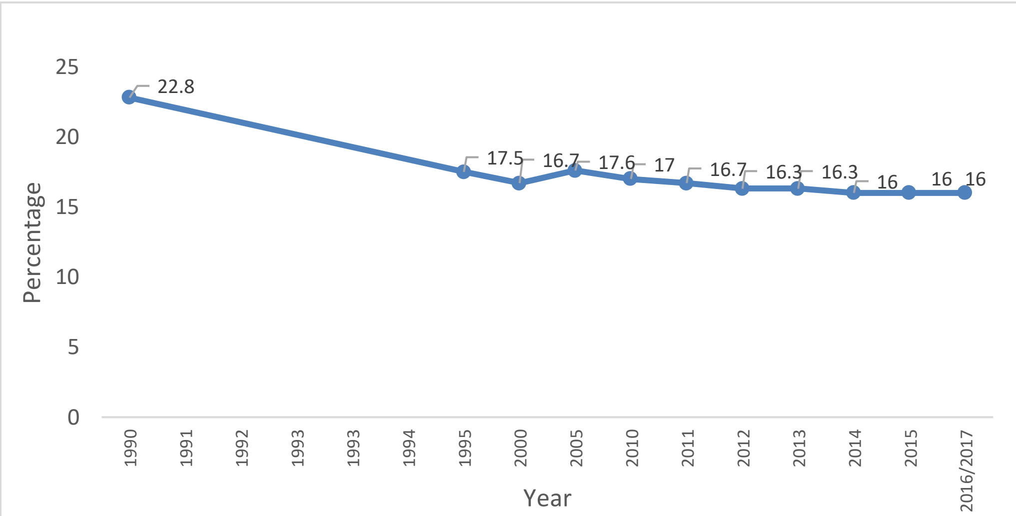
Recent research studies applied multilevel models to examine the impact on individual, household and community level effects of birth weight. Many of these studies considered two-level models, the individuals nested within the community level (Kayode et al., 2014; Young et al., 2010). A multilevel analysis on the influence of individual and community factors on preterm birth in Sub Saharan Africa also confirmed that being a rural mother in a poverty concentrated community has an increased risk of having a LBW infant (Kayode et al., 2014).

4.5 Low birth weight puzzle in Sri Lanka

Sri Lanka has been acknowledged globally for its remarkable achievement in health indicators (The World Bank, 2015a; United Nations, 2016; World Health Organization, 2015a). Referred to as one of the good health models, Sri Lanka has low maternal mortality, low infant and child mortality and longer life expectancy at birth (World Health Organization, 2015a). However, nutrition-related indicators show little progress over the last two decades (World Health Organization, 2014b).

In particular, LBW has remained relatively constant at a high level, over the last decade (Ministry of Health Nutrition and Indigenous Medicine, 2015). For example, LBW has fluctuated between 16 per cent and 18 per cent over the last two decades and according to the 2016 DHS remains at 16 per cent (Department of Census and Statistics, 2017). This trend is illustrated in Figure 4.1.

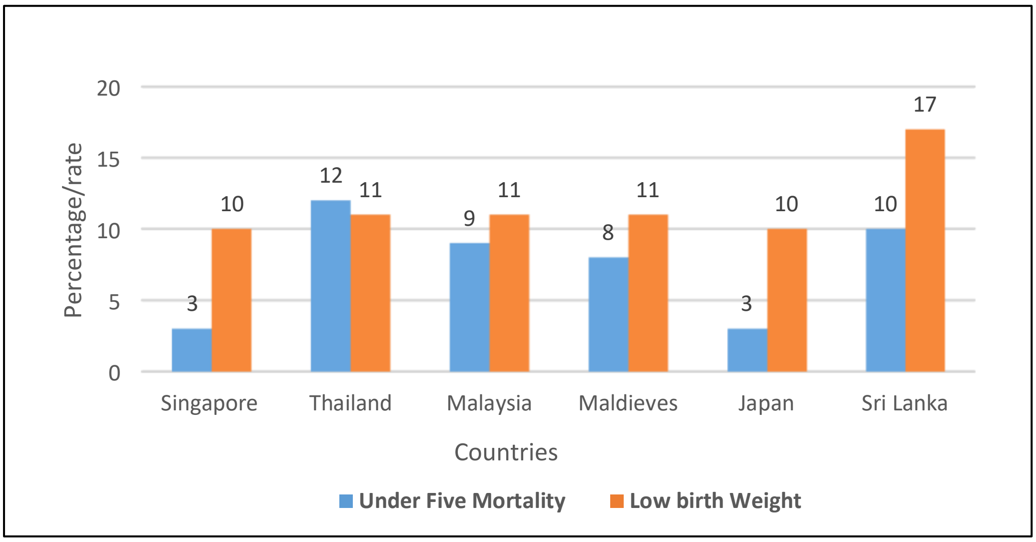
Figure 4.1 Low birth weight rate in Sri Lanka from 1900-2017



Author's own analysis (Data source: Department of Census and Statistics, 2017)

In South Asia, the majority of babies are born with low birth weight (UNICEF, 2015). For instance, LBW rates have been reported at 28 per cent and 32 per cent in India and Pakistan respectively. However, the LBW rate is lower in Sri Lanka compared to its neighbouring countries. As illustrated in Figure 4.2, Sri Lanka managed to achieve faster reductions in under 5 mortality rates, similar to the levels of other Asian countries with high and middle GDP levels. However, as shown in Figure 4.2, this is not the case for its low birth weight.

Figure 4.2 Under 5 mortality rates and low birth weight rate in selected Asian countries



Author's own analysis (Data source: United Nations Children's Fund (2018)

The stagnant rates of low birth weight raise a multifaceted public health problem in Sri Lanka due to the long term impact on health outcomes (Ministry of Health Nutrition and Indigenous Medicine, 2015). The situation of LBW in Sri Lanka adds a substantial financial burden to the health sector in Sri Lanka. Despite some actions taken by the government on maternal, child health and universal access to antenatal care (Food/micronutrient supplementation programmes, National health policy -2011, Poverty alleviation programmes), there is a little reduction in LBW outcomes (Rajapaksa et al., 2011).

Research on the prevalence and determinants of LBW has been conducted in the context of Sri Lanka. These studies have shown determinates of low birth weight, that can be broadly classified as maternal nutritional, genetic obstetric, socioeconomic and environmental factors.

A study conducted in a rural setting highlighted, maternal nutrition, maternal workload, poverty and maternal infection as risk factors associated with LBW. This study suggests increasing the nutritional level of mothers, and antenatal visits as the key interventions to reduce low birth weight (Galmangoda et al., 2017). Another study carried out in the Eastern Province of Sri Lanka, identified parental education as a risk factor for low birth size among the children (Herath, 2016).

Furthermore, the best predictors of low birth weight are identified as the maternal BMI of 23.7 kg/m^2 or below 13 weeks of gestation, which contributed 80 per cent of sensitivity for birth weight for mothers who participated in the antenatal visits in Jaffna District (Jananthan et al., 2010). Anuranga et al. (2012) investigated the inequalities of low birth weight (LBW) and found maternal body mass index (BMI), height and education, altitude and ethnicity as the major determinants of LBW. A hospital-based survey conducted on the growth parameters of babies in Gampaha District reported that the mean birth age was 2.92 kg (Perera et al., 2013). Birth order, family income and maternal education were significantly associated with growth parameters in the same study.

Most of the low birth weight studies were conducted in specific settings, e.g., rural or hospital-based studies, often with small samples representative of a district or a hospital. There is a little systematic investigation of factors associated with LBW at the national level in the post-conflict period in Sri Lanka. The present study will investigate maternal depletion factors, socioeconomic factors and geographic factors associated with birth weight in the context of Sri Lanka.

4.6 Objectives and research hypotheses of the study

The study addresses the following research objectives

1. To examine how low birth weight distributed among different socioeconomic groups and across residential sectors and geographical provinces.
2. To explore the association between maternal nutrition depletion and low birth weight outcomes.
3. To examine socioeconomic inequalities of low birth weight by different residential sectors.
4. To examine how maternal household and geographic factors are associated with low birth weight at the maternal, household and community levels.

Research hypothesis

The Indian Tamil population predominantly live the estate sector (nearly 83 per cent) who were the Indian origin population, partly descended from South India to Sri Lanka in the 19th century, to work on plantations (Anuranga et al., 2012; Sinnathurai and Olga, 2012). They are identified as a disadvantaged group who have the lowest level of living and they experience conditions of severe poverty conditions (Dharmadasa and Polkotuwa, 2016; Jawid, 1985; Sinnathurai and Olga, 2012). Low birth weight found to be worse for estate Indian Tamil children, who have the highest prevalence of low birth weight (Anuranga et al., 2012; Jayawardena, 2014) as nearly one in three babies is born as low birth babies. It also been reflected the intergenerational cycle of malnutrition exists among Indian Tamils mothers live in estate sector, who are poorly nourished during their childhood are likely to give birth to low birth weight babies, who are expected to be undernourished during their childhood. For instance, around 33 per cent of estate sector women were reported as undernourished compared to their counterparts living in urban and rural areas. Drawing on findings from previous studies, this study hypothesises that LBW is associated with socioeconomic disadvantage. Children born in poor households and to the Indian Tamil tea plantation workers in the estate sector are more vulnerable to LBW outcomes than their counterparts living in richer households in other rural and urban areas.

4.7 Data and methods

The birth weight of the children was obtained through Child Health Development Record (CHDR) for all children who were born since January 2011 (0-59 months) up to the date of the interview in 2016. It was able to obtain the birth weight data from the CHDR for 97 per cent of these children. There were, in total 8,104 live births reported and among these 7964 (98.3 per cent) were reported as singleton births. There were 140 multiple births (1.7 per cent) recorded, among them a higher proportion (113-80.7 per cent) tend to be LBW babies. These multiple births, socioeconomic factors are distributed similarly to singleton babies. Therefore, the analysis excluded 140 (1.7 per cent) multiple births and those with an extremely high birth weight above 6500-9000 grams (0.36 per cent). The final analysis sample considered 7,713 (after excluding missing cases) live singleton births with a birth weight ranging from 400 to 6500 grams.

4.7.1 Outcome variable

The birth weight variable is used as a continuous outcome for the linear regression models and a dichotomous outcome for the logistic regression models. For the continuous outcome, valid birth weights ranged between 400-6500 grams are used. For the categorical outcome birth weight was categorized into 2 groups: NBW- normal birth weight (birth weight >2,500g, coded 0) or LBW- low birth weight (birth weight<=2,500g, coded as 1). According to the WHO definition, LBW is generally defined as birth weights less than 2500 grams. However, there is potential heaping on birth weight data from population-based retrospective surveys such as DHS as people tend to round and express digits that are multiples of 500 grams, irrespective of the unit of measurement (Blanc and Wardlaw, 2005; Channon et al., 2011)

Since the birth weight data were extracted from the health records, rounding to the approximate digit at the reporting could be expected from the current survey. This study reported 220 observations (2.6 per cent) heaped at 2500 grams, assuming that a newborn reported as weighing 2500 g, actually weighed as less than 2500 grams. Therefore, actual low birth weight born baby could be misclassified as a normal birth baby, so the prevalence of low birth weight will be biased (Blanc and Wardlaw, 2005). Therefore, to overcome the influence of potential heaping, low birth weight is defined as weight equal and less than 2500 grams (<=2500 g) at birth.

4.7.2 Explanatory variables

The selection of explanatory variables for this study is based on the literature review and conceptual framework (Chapter 2). This study categorized explanatory variables into three categories: maternal depletion variables, socioeconomic variables including household factors and geographic variables (Table 4.1).

a. Maternal depletion variables

Maternal depletion variables are selected based on the concept of maternal depletion discussed in the literature review section. The DHS includes a limited number of questions capturing maternal depletion that directly or indirectly influence maternal depletion. The survey asked mothers to report their gestational age in months. However, we did not use this information since the reported gestational data (in months) could be biased and grossly underestimated.

Hence, this study only considered factors such as maternal age, anthropometric measures of women including maternal age, BMI (Body Mass Index), BMI variable was squared to check the evidence of a nonlinear association between birth weight and BMI in the multiple linear regression models, maternal stature (height), preceding birth intervals, intake of micronutrients (IFA-iron and folic acid), a number of antenatal visits and child's sex status. The frequency of antenatal visits ranged from 1 to 15 visits were used as a continuous variable in the linear regression model and was coded in the logistic regression model.

Further, the consumption of food supplementation (Thriposha- triple nutrient) provided by the government to pregnant mothers which is being considered as essential for enhancing maternal nutrition was also considered.

Table 4.1 Definition and coding of variables for analyses presented in Chapter 4

Variable	Definition and coding
Maternal depletion variables	
Maternal age (years)	Coded as <=20, 21-29, 30-34, 35 or more years
Maternal height	categorised as (1) short (≤145 cm); (2) average (145.1-155 cm); (3) tall (155.1 cm)
Maternal BMI	Coded as (1) low BMI (<18.5); (2) normal or healthy weight (18.5-24.9 kg/m2); (3) overweight; (BMI 25 -29.9 kg/m2); (4) obese (BMI >=30 kg/m2)
Marital status	Grouped into 2 categories: (1) married/cohabiting; (2) widowed/divorced/separated
Birth interval	Coded as (1) first birth; (2) less than 24 months; (3) 24-47 months; (4) 48 months & over
Intake of micronutrients	Coded as (1) received and consumed; (2) not received and not consumed
consumption of food supplementation (IFA)	Coded as (1) received and consumed; (2) received and shared;(3) not received not consumed
Number of anc visits	Coded as (1); Below 3 times;(2) 3-5 times;(3) 6-10 times;(4)11 and over
Sex	Coded as (1) male; (2) female
Maternal socioeconomic household factors	
Maternal age (years)	Coded as <=20, 21-29, 30-34, 35+ years
Marital status	Grouped into 2 categories: (1) married/cohabiting; (2) widowed/divorced/separated
Educational status	Mother's highest level of completed education. Categorised as (1) up to and including grade 5; (2) grade 6 to O/L (Ordinary level); (3) passed GCE Advanced Level (A/L); (4) Degree and above
Maternal employment status	Coded as (1) currently working outside the household; (2) not working outside the household
Maternal ethnicity	Grouped according to the major ethnic groups: (1) Sinhala;(2) Sri Lankan Tamil;(3) Indian Tamils; (4) Muslim, Malay, and Burgher ethnicities
Household wealth index	Quintiles of household wealth, Coded as: (1) poorest; (2) poorer; (3) middle; (4) richer; (5) richest
Number of household members	classified as (1) less than five members; (2) 5-7 members; (3) 8 or more members
Residential /community factors	
Residential sector	Coded as (1) urban; (2) rural; (3) estate
Geographical province	Nine provinces, corded according to the administrative classification of Sri Lanka
Community poverty	Classified as (1) low, if the proportion of individuals in the community at least in poorer and poorest wealth quintiles is less than 40 per cent (2) high, if the proportion in community at least in poorer and poorest wealth quintiles is 40 per cent or more
Community maternal education	Classified as (1) low, if the proportion of mothers with at least completed O/L is less than 42 per cent); (2) high, if the proportion of mothers with a least completed O/L is 42 per cent or more

4.7.3 Descriptive analysis

Key socioeconomic and demographic characteristics of the children in the past 5 years preceding the survey (0-59 months) and their mothers were examined. Descriptive characteristics for continuous variables are presented as means and standard deviations and as percentages for categorical variables. Chi-square tests were performed to identify the variables associated with low birth weight, before considering those in multiple regression analyses. The significance level is set at a 95 per cent level for all variables. Data analysis was performed using Stata 15.0. SVY command was used to account for the DHS complex sample design. The prevalence of low birth weight across the districts was compared using the 2006 and 2016 DHS surveys. Maps were constructed using ArcGIS software V 10.6. Concentration Index (CI) and Concentration Curves (CC) on low birth weight by residential sectors were applied to measure the magnitude of socioeconomic inequalities across residential sectors.

4.7.4 Model building

This study applied both multiple linear and multiple logistic regression analyses to examine the independent strength of association of each explanatory variable with birth weight. Linear regression models can be applied to explore the factors that affect birth weight; however, logistic regression models will be used to predict the independent effect of factors associated with low birth weight. The difference between these two methods is the nature of the outcome variables and the nature of the assumptions underlying the model. Otherwise, the two methods follow the same principles and considerations. For both methods, the same factors were considered and there were 3 models for each regression method, as illustrated in Table 4.2.

Table 4.2 Model-building framework for birth weight outcome

Model selection			
Model 1	Maternal factors		
Model 2	Maternal factors	Socioeconomic/household factors	
Model 3	Maternal factors	Socioeconomic/household factors	Geographic factors including residential sectors and provinces

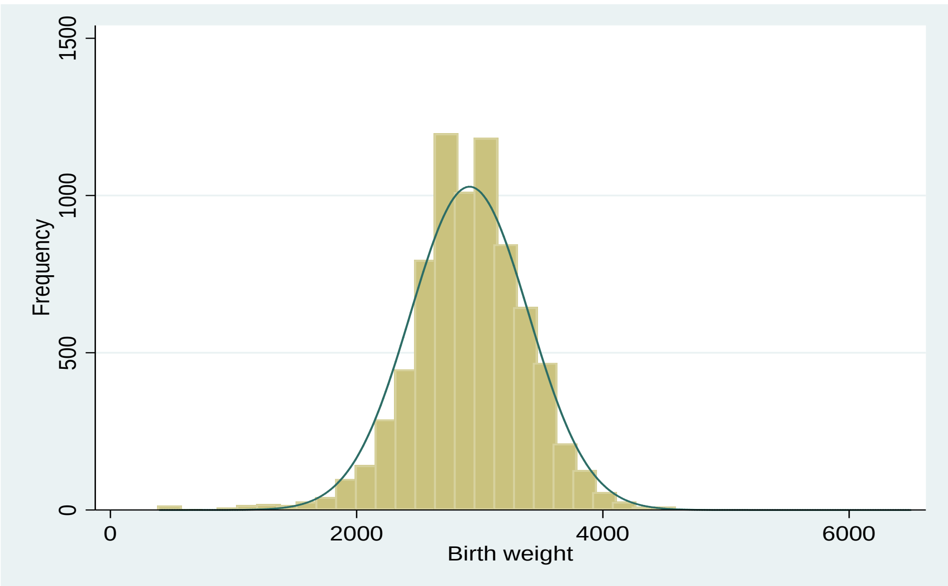
4.7.5 Analysis of missing data

It is vital to understand the extent of missing data in any study to decide how to deal with it. There were 201 total cases (2.54 per cent) either missing or not recorded on the card reported – which was not a substantial value. Residence and wealth quintiles were used to assess missing birth weight data. The rural sector had the highest number of missing data with 157 cases (0.7 per cent), while the estate sector had the lowest missing cases (28 cases, 0.12 per cent). In the case of wealth index, birth weight in the fourth and highest wealth quintiles had less number of missing cases (0.1 per cent for both), while the lowest and second-lowest quintiles had missing cases of 0.4 per cent and 0.2 per cent respectively. Since the number of observations with complete data is sufficiently large for the birth weight data, missing cases have been excluded from the study.

4.8 Results of the descriptive analysis

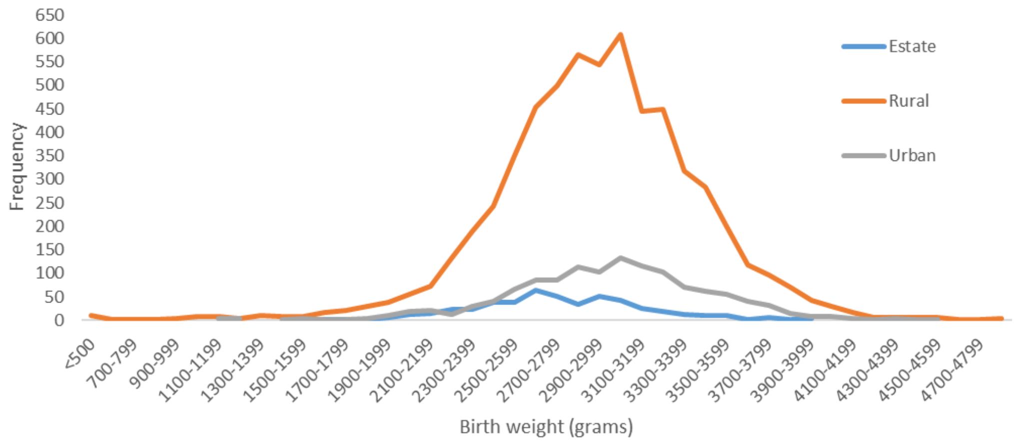
Of 7,713 babies born during the 5 years preceding the survey, the percentage of births with a LBW was 16.9. The mean birth weight was estimated at 2917 grams (SD: 480.5) for those children with a reported birth weight (Figure 4.3). Birth weight distribution was examined by the residential sectors, as presented in Figure 4.4. The highest numbers of births were reported in the rural sector and the estate sector had the lowest number of births. Mean birth weight for urban, rural and estate sectors was estimated at 2977, 2920 and 2719 grams respectively. As seen in Figure 4.5 most of the births among urban and rural sector were overlaid on the rural sector, due to a large number of births reported in the rural sector (5972).

Figure 4.3 Distribution of birth weight in Sri Lanka (Birth weight 400-6500 in grams)



Source: Author’s own analysis based on the data from the Department of Census and Statistics, 2017

Figure 4.4 Birth weight distribution by residential sector



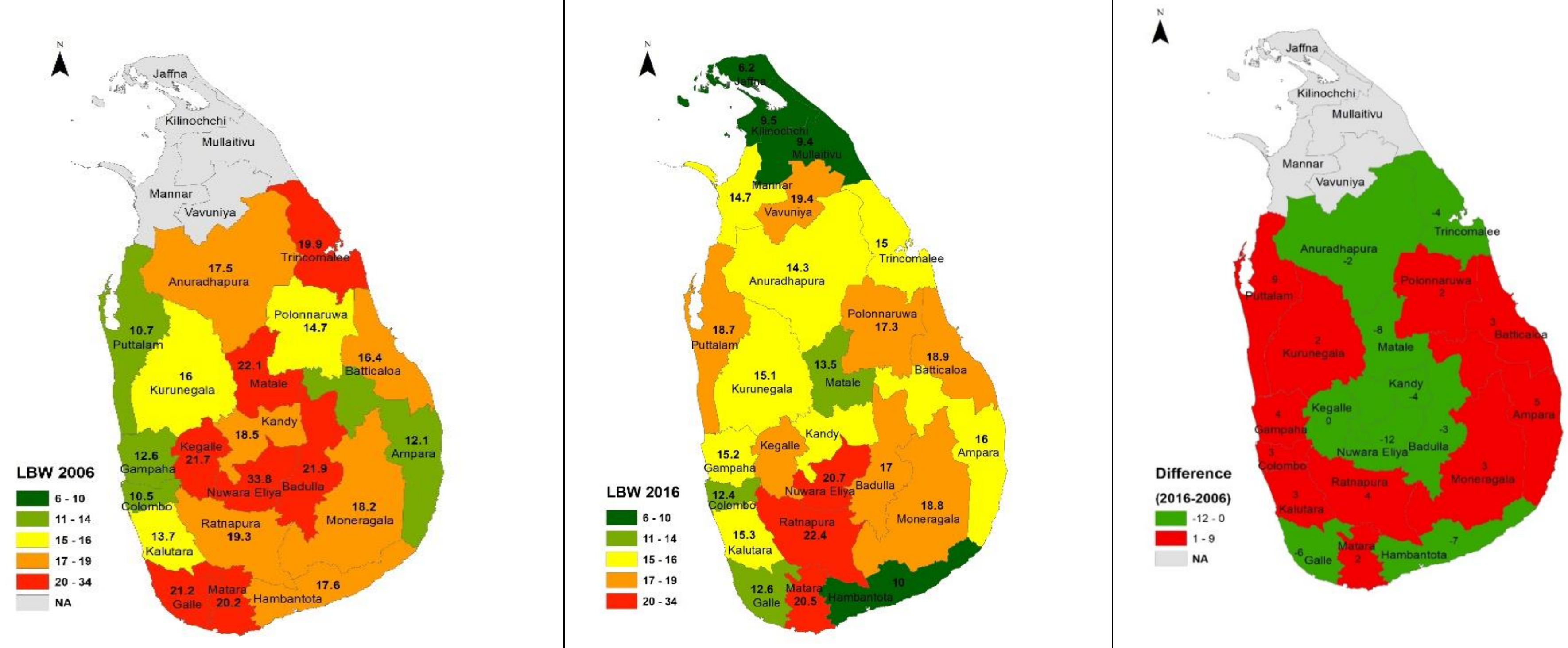
Author's own analysis (Data source: Department of Census and Statistics, 2017)

4.8.1 Distribution of Low birth weight in Sri Lanka by district

The distribution of low birth weight by districts in SLDHS 2006 and SLDHS 2016 is presented in Figure 4.5. Due to security reasons attributed to the conflict, data was not collected for the Northern Province in the 2006 SLDHS. In SLDHS 2006, Nuwara-Eliya (33.8 per cent), Matale (22.1 per cent) and Badulla (21.9 per cent) accounted for the three districts with the highest prevalence of low birth weight babies, while Colombo (10.5 per cent), Puttalam (10.7 per cent) and Ampara (12.1 per cent) districts reported the lowest.

The distribution of low birth weight has changed significantly in SLDHS 2016. Ratnapura district shows the highest prevalence of 22.4 per cent which is nearly a 3 per cent increase compared to the SLDHS 2006. Nevertheless, Nuwara-Eliya district shows a remarkable reduction of 13.1 percentage compared to the figure 33.8 reported in 2006. Galle, Matale and Hambantota also recorded reductions in low birth weight babies. Overall, during 2006-16, the low birth weight rate for Sri Lanka varied considerably by districts – although the overall level remained constant. Low birth weight rates declined by comparable magnitudes in 10 districts, highlighted in green colour. The decline was more pronounced in Nuwara-Eliya, Galle, Matale and Hambantota districts. However, in some districts, the proportions of low birth weight have increased compared to the DHS 2006. The increase was marked in 10 districts, including Puttalam and Ratnapura. These changes are highlighted in the 1c map in Figure 4.5. The low birth weight distribution in the Northern Province districts remained the lowest (6-10 per cent). The increase in low birth weight in 2016 for some districts, in particular, in districts such as Colombo, Gampaha and Kalutara possibly contributed to the overall value of low birth weight at the national level. LBW data was also calculated using the LBW definition as<=2500g grams for SLDHS 2016 (results were not reported). There were no large differences in the percentages of the district for both LBW definitions; <2500 g and <=2500g (the difference is less than 4 per cent in each district).

Figure 4.5 Distribution of LBW prevalence in SLDHS 2006 and 2016 and changes by Districts in Sri Lanka*



1a: LBW distribution in 2006

1b: LBW distribution in 2016

1c: LBW distribution difference 2006-2016

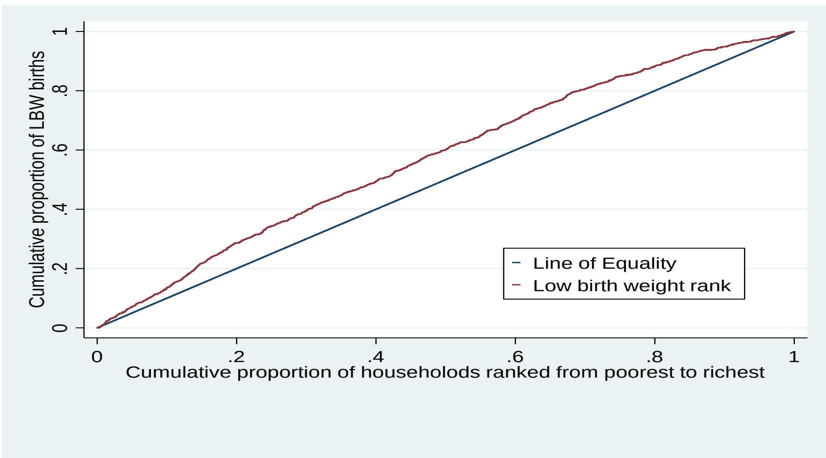
Author's own analysis (Data source: Department of Census and Statistics, 2017 *Due to the unavailability of DHS 2006 data Low birth weight was graphed using <2500 grams among children 0-59 months for both years to maintain consistency.

4.8.2 Socioeconomic inequalities in low birth weight

We measured socioeconomic inequality in the prevalence of low birth weight using the concentration curve (CC) and the concentration index (CI). The results show a concentration index value of -0.13 (95 per cent CI: -0.15, -0.10, $p<0.001$) for low birth weight, which suggests low birth weight is more concentrated among the poorest households. Figure 4.6 displays a Concentration Curve of inequality for low birth weight. CC is a graphical illustration of CI, and it exemplifies the cumulative proportion of low birth weight children plotted against the cumulative proportion of the population ranked by the poorest to richest wealth quintiles. According to Figure 4.6, CC lies above 45^{o} of the line of equality line, which suggests the prevalence of LBW is higher among people with lower income than those with higher income.

The patterns of CI for LBW in Sri Lanka observed over time show a progressive increase from 1993 (CI= -0.14) to 2000 (CI= -0.20). Thereafter, it dropped during 2006/07 (CI= -0.13) (Anuranga et al., 2012). The value of the CI of -0.13 in 2016 suggested the degree of inequality in low birth weight was the same after a decade (DHS, 2016). However, one should exercise caution comparing CI values over time due to measurement incomparability, such as restricted birth weight and island-wide coverage of data in the present study.

Figure 4.6 Concentration curve of cumulative LBW by wealth quintile



Source: Author's own analysis

This study further investigated the difference in socioeconomic inequality of low birth weight by residential sectors. Figure 4.8 captures the inequality of low birth weight due to the variability of income across different residential sectors. This was derived by ranking the people in each corresponding sector according to their income groups.

As shown in Figure 4.7, concentration curves for all sectors lie above the equality line, which suggests that the low birth weight was greater among the children of poorer households in each sector. However, when we compare the level of inequality within each residential group; our results confirmed that socioeconomic inequality of low birth weight was more than two times higher in the urban sector compared to estate areas. Rural sectors reported the highest income inequality in child low birth weight compared to other counterparts (Table 4.3).

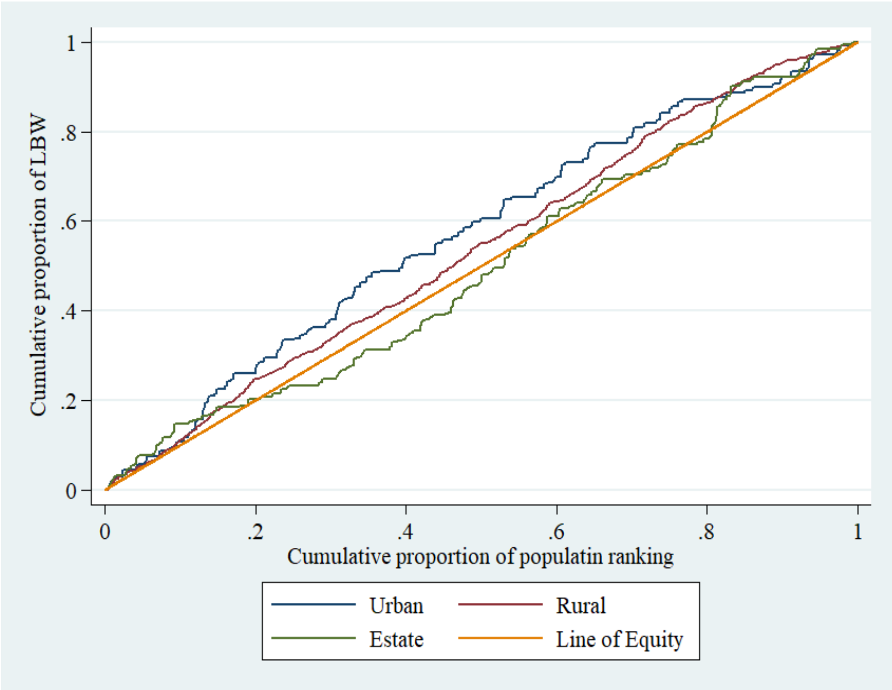
This study further graphed concentration curves, considering the between inequality which captures the variability of total income within each residential sector (Appendix B). The results show that the socioeconomic inequality in low birth weight was the highest in the Estate sector, which lies above the inequality line. This implies that pro - poor inequality exists in the Estate sector while pro - rich inequality exists in the urban sector. This could be attributed to the low socioeconomic household status in the estate sector compared to other sectors. For example, in the current survey, the majority of households in the estate sector (73 per cent) fell into the lowest wealth quintile while urban and rural sectors had 8.41 and 24.1 percentages belong to the lowest wealth quintiles.

Table 4.3 Concentration index for each residential sector

Residential sector	Concentration index value	P value	Confidence interval
Urban Sector	-0.078	0.091	-0.169,0.0125
Rural Sector	-.122***	0.000	-0.157, -0.088
Estate sector	-0.032	0.469	-0.121, 0.055

****p*-values: Independent 2-tailed *t*-test to compare the values of the concentration indices equals 0.

Figure 4.7 Concentration curves by residential sectors, considering the cumulative proportion of households ranked between sectors



Source: Author's own analysis

4.8.3 Results of the bivariate analysis

The association between maternal depletion factors and socioeconomic and geographic factors by birth weight is explored by undertaking cross-tabulations of the variables described in Table 4.4. Birth weight data has been categorized into four categories: <=2500, 2501-2999, 3000-3499 and 3500-6500 grams. Mean birth weight was obtained for each variable and confidence intervals are also presented. Since all the variables were treated as categorical variables, including maternal BMI, height and antenatal visits, chi-square *p*-value are given, showing whether the difference in the birth weight outcome is statistically significant or not. It is shown that both maternal and socioeconomic factors were significantly associated with low birth weight.

According to the findings, low birth weight was more concentrated among teenage and young mothers (<19 and 20-24 years). There is a positive association between BMI and birth weight and between the height of a mother and birth weight (p value<0.000). Even though there is an association with antenatal visits, there was no significant association with the receipt of Thriposha during pregnancy. However, LBW was more common among mothers who had not received and consumed IFA supplements. Female babies were 3.6 per cent more likely to be LBW.

When the socioeconomic characteristics were analysed, LBW was inversely related to educational attainment. Further, LBW was negatively associated with household wealth. For example, 21.4

per cent of mothers in the lowest wealth quintile had the highest number of low birth weight babies. Indian Tamils were more likely to have had a LBW baby and have lower birth weights than other ethnic groups. Estate residents have the highest low birth weight compared to other residents at 28.4 per cent. LBW was less likely in the Northern region but more likely in the Central and Sabaragamuwa regions. Community characteristics are significantly associated with low birth weight, about 18.9 per cent of low birth weight babies are reported in communities with poor maternal education and 19.3 per cent babies from poor communities.

Table 4.4 Distribution of a birth weight by socioeconomic geographic factors with Chi-square test of association (N=7,713)

Characteristics	<=2500 (n=1303)	2501-2999 (n=2929)	3000-3499 (n=2692)	3500-6500 (n=789)	Mean (Min.-Max.)	No. of births (n=7,713)	p-value
Total	**16.89**	**37.97**	**34.9**	**10.23**	**2917.5**	**7,713**	
Maternal age							
<=20	26.8	41.7	26.8	4.5	2802.6 (2704.8-2900.4)	175	
21-29	18.2	39.8	33.7	8.1	2838.4 (2808.7-2868.7)	2,924	0.001
30-34	14.6	37.0	37.1	11.2	2926.7 (2913.1-2940.3)	2,455	
35+	16.8	36.2	34.5	12.3	2945.3 (2920.8-2969.9)	2,159	
Maternal BMI						n=7,545	
<18.5	26.4	45.5	24.4	3.5	2732.4 (2702.9-2761.9)	847	
18.5-24.9	17.2	39.9	33.9	8.8	2897.6 (2883.0-2912.2)	3,726	0.000
>=25-29.9	14.1	33.9	38.4	13.5	2986.7 (2966.1-3007.8)	2,171	
>=30	11.8	31.9	40.1	15.9	3033.1 (2999.5-3066.8)	801	
Maternal height						n=7,564	
Short <=145 cm	28.8	41.2	24.5	5.3	2754.4 (2716.9-2792.0)	545	0.000
Average 145.1-155 cm	18.5	39.6	32.9	8.7	2881.2 (2867.1-2895.2)	4,198	
Tall 155.1 & over	12.0	34.8	39.5	13.5	3006.0 (2988-3-3023.7)	2,821	
Antenatal visits						n=7,713	
Below 3 times	17.2	37.9	35.6	9.1	2892.4 (2825.1-2913.9)	1,526	
3-5 times	25.1	37.6	29.7	7.4	2813.3 (2801.8-2905.0)	589	0.001
6-10 times	16.1	38.1	35.0	10.6	2930.8 (2928.4-2960.2)	5,314	
11 & over	12.3	36.2	38.3	13.0	3008.5 (2939.2-2994.3)	284	

Characteristics	<=2500 (n=1303)	2501-2999 (n=2929)	3000-3499 (n=2692)	3500-6500 (n=789)	Mean (Min.-Max.)	No. of births (n=7,713)	p-value
Total	**16.89**	**37.97**	**34.9**	**10.23**	**2917.5**	**7,713**	
Received Thriposha						n=6,528	
Received & consumed	18.5	43.8	30.5	7.3	2859.4 (2818.1-2900.7)	504	0.108
Received and shared	17.0	37.5	34.8	10.5	2921.1 (2908.9-2933.3)	5,921	
Not received and not consumed	9.7	40.7	37.8	11.6	2962.8 (2881.0-3044.7)	103	
Taken IFA supplements						n=6,736	
Received & consumed	16.5	38.1	35	10.3	2921.5 (2910.1-2932.8)	6503	0.000
Not received and not consumed	25.7	36.0	26.6	11.5	2832.4 (2743.0-2921.8)	233	
Sex of child							
Male	15.1	37.4	36.3	11.3	2944.2 (2929.2-2959.2)	4,000	0.000
Female	18.7	38.8	33.5	9.0	2888.5 (2873.2-2903.8)	3,794	
Birth interval							
First birth	19.5	40.6	32.0	7.7	2862.2 (2845.3-2879.1)	3,011	
< 24 months	14.9	34.5	36.5	13.9	2938.1 (2884.6-2991.6)	394	0.000
24-47 months	12.7	35.5	39.1	12.5	2988.9 (2966.3-3011.6)	1,584	
48 months or more	16.7	35.3	36.4	12.9	2970.5 (2935.8-3005.2)	2,724	
Educational category							
Up to grade 5	27.6	40.2	24.7	7.3	2756.3 (2623.6-2889.0)	380	
Grade 6 to Ordinary Level	18.0	38.4	33.7	9.7	2784.9 (2733.8-2835.9)	5,127	0.000
Advanced Level	11.6	39.0	38.0	11.2	2885.6 (2869.6-2901.7)	1,761	
Degree and above	15.0	26.2	44.7	13.9	2927.4 (2904.9-2949.9)	445	
Wealth index							
Lowest	21.4	40.6	29.8	8.0	2838.2 (2816.9-2859.5)	1,900	

Characteristics	<=2500 (n=1303)	2501-2999 (n=2929)	3000-3499 (n=2692)	3500-6500 (n=789)	Mean (Min.-Max.)	No. of births (n=7,713)	p-value
Total	**16.89**	**37.97**	**34.9**	**10.23**	**2917.5**	**7,713**	
Secondary	17.8	38.0	35.3	8.7	2899.5 (2876.5-2922.6)	1,571	0.000
Middle	17.9	38.5	33.2	10.2	2905.4 (2879.9-2903.9)	1,460	
Fourth	14.1	36.5	37.8	11.4	2959.1 (2935.1-2983.1)	1,514	
Highest	10.8	34.9	40.3	13.8	3020.5 (2994.7-3046.3)	1,268	
Ethnicity							
Sinhala	17.2	38.0	34.5	10.0	2913.5 (2900.2-2926.8)	5,025	
Sri Lanka Tamil	15.9	36.4	36.8	10.8	2941.7 (2918.3-2965.0)	1,564	0.000
Indian Tamil	32.6	42.5	23.5	1.2	2637.2 (2751.4-2703.0)	242	
Muslims and others	12.1	38.6	36.7	12.4	2927.7 (2942.8-3002.7)	882	
Residential sector							
Urban	13.6	34.4	38.5	13.2	2977.4 (2951.0-3003.9)	1,249	
Rural	16.6	38.1	35.2	10.0	2920.8 (2908.6-2932.9)	5,972	0.000
Estate	28.4	45.1	21.9	4.4	2719.7 (2679.3-2760.1)	492	
Province							
Western	14.5	37.8	36.5	11.1	2954.8 (2931.2-2978.3)	1,455	
Central	20.2	38.8	32.7	8.3	2858.3 (2828.0-2888.6)	996	0.000
Southern	16.4	38.1	34.3	11.0	2937.0 (2907.4-2966.7)	923	
Northern	12.0	34.4	40.3	13.1	3004.3 (2973.2-3035.3)	905	
Eastern	17.0	37.5	35.0	10.3	2911.5 (2882.5-2940.4)	857	
North-Western	17.1	34.9	35.7	12.1	2951.8 (2919.5-2984.1)	832	
North-Central	14.3	42.4	33.2	10.0	2920.9 (2881.7-2961.1)	530	
Uva	18.7	41.0	35.1	4.9.0	2833.8 (2794.1-2873.5)	543	
Sabaragamuwa	24.1	39.7	27.9	8.1	2806.5 (2762.7-2850.4)	672	

Characteristics	<=2500 (n=1303)	2501-2999 (n=2929)	3000-3499 (n=2692)	3500-6500 (n=789)	Mean (Min.-Max.)	No. of births (n=7,713)	p-value
Total	**16.89**	**37.97**	**34.9**	**10.23**	**2917.5**	**7,713**	
Community maternal education							
Low	18.9	38.7	32.9	9.4	2888.7 (2795.1-2901.3)	4,472	0.000
High	14.0	36.9	37.6	11.3	2956.5 (2902.4-2988.1)	3,241	
Community poverty							
Low	14.6	37.4	36.9	11.0	2945.1 (2932.4-2971.3)	4,000	
High	19.3	38.5	32.7	9.3	2882.7 (2798.3-2912.2)	3,713	

*P < 0.05 **P<0.01*** P<0.001

4.9 Results of the multivariate analysis

4.9.1 Results of multiple linear regression

Table 4.5 shows the results of the linear regression analysis, investigating the factors affecting birth weight among children aged 0-59 months at the time of the survey. Maternal depletion variables in the first model, such as birth interval, maternal height, body mass index (BMI), BMI squared, the number of antenatal care visits, and the sex of the child are significantly associated with birth weight in the expected directions. The coefficient for BMI squared is -0.40 with 95 per cent CI (-0.7, -0.5), indicating that the association between BMI and birth weight is non-linear. The model also highlights the importance of attending antenatal care visits and birth intervals as strong factors associated with the birth weight outcome ($p<0.001$). Female children are approximately 63 grams lighter than male babies in the sample. Maternal age ($p = 0.76$), receiving and consumption of iron and folic acid ($p = 0.18$), were statistically not significant with birth weight once other covariates were included in the earlier model, therefore these variables have been removed from the final model.

The second model, controlling for maternal and socioeconomic factors, shows that compared with mothers with primary education, babies are, on average, nearly 100 grams heavier among mothers with high educational qualifications such as 'degree-level and above'. Further, mothers in the highest wealth quintiles have babies who weigh nearly 107 grams (on average) more than the babies of mothers in the lowest wealth quintiles. Similarly, ethnicity was found to be a crucial factor in determining the birth weight: babies born to mothers belonging to the Indian Tamil ethnicity are 175 grams lighter (on average) than children born in other ethnic groups.

In the final model, geographic factors were added to the second model in addition to the maternal depletion and socioeconomic factors. Maternal depletion factors remained statistically significant with wealth; however, maternal education, community education and community poverty do not show any statistical significance. The residential sector was not significant, after controlling for ethnicity in the model. It may be that the majority of Indian Tamils represent the estate sector and the total number of estate Indian Tamil births are less representative compared to the other sectors.

According to the final model, the effects of the BMI, maternal height, education and ethnicity effect have been reduced compared to Model 2. For example, the Indian Tamil mothers in the estate sector are likely to have babies with an average birth weight of 167 grams lower compared to the women belonging to other ethnicities. Compared to the other nine provinces, Northern and

Sabaragamuwa Provinces appeared to be significantly associated with birth weight. Infants of mothers from Sabaragamuwa Province had an average birth weight of 69 grams less than infants in the Western Province ($p < 0.01$). Overall, the regression results clearly demonstrate that maternal depletion variables have a very strong influence on birth weight compared to socioeconomic and spatial variables. The R2 value of the three models reported an increasing trend of 7%, 8% and 10% respectively, showing that about 10 % of the variability in birth weight data is accounted for by the covariates in the model.

Table 4.5 Results of the multiple linear regression for models adjusting for maternal, socioeconomic and geographic factors

	Model 1	**Model 2**	**Model 3**
Variables	**Coef. (95 per cent CI)**	**Coef. (95 per cent CI)**	**Coef. (95 per cent CI)**
Maternal Body Mass Index	38.4 (20.6, 26.1) ***	31.2 (17.3, 48.1) ***	31.6 (15.7, 47.5) ***
Maternal Body Mass Index squared	-0.40 (-0.7, -05) **	-0.31 (-0.6, -0.002) ***	-0.33(-0.6, -0.01) *
Maternal height (cm)	12.8 (10.7,14.9) ***	11.7 (9.7-13.7) ***	11.4 (9.4,13.1) ***
Number of anc visits	7.1 (3.8,10.5) ***	8.2 (4.9,11.6) ***	7.8 (4.4,11.2) ***
Preceding birth interval			
First birth	1.00	1.00	1.00
< 24 months	74.6 (18.9,130.3) **	76.1 (21.8,130.4) ***	76.7 (22.5,131.0)
24-47 months	112.9 (84.6,141.2) ***	119.4 (90.5,147.5) ***	119.5 (90.9,148.0) ***
48 months or more	48.7 (22.8,74.6) ***	63.4 (37.7,89.2) ***	65.2 (39.5,91.0) ***
Sex of a child			
Male	1.00	1.00	1.00
Female	-63.1 (-85.4, -40.9)	-62.9 (-85.9, -41.6) ***	-63.2 (-85.2, -41.3) ***
Educational category			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		42.9 (-17.1,102.9)	32.6 (-28.2,93.6)
Advanced Level		67.2 (1.3,133.1) *	57.1 (-9.5,123.8)

	Model 1	Model 2	Model 3
Variables	Coef. (95 per cent CI)	Coef. (95 per cent CI)	Coef. (95 per cent CI)
Degree and above		99.1 (18.5,179.8) *	82.9 (1.3,164.5)
Wealth index			
Lowest		1.00	1.00
Second		40.9 (5.4, 76.4) *	45.1 (9.5, 80.7) *
Middle		38.3 (-0.6, 77.2)	42.5 (3.4, 81.5) *
Fourth		70.8 (32.7, 108.9) ***	72.2 (33.8, 110.6) ***
Highest		107.3 (60.4,154.3) ***	108.0 (57.9,158.1) ***
Ethnicity			
Sinhala		1.00	
Sri Lankan Tamil		58.3 (26.3,90.3) ***	29.4 (-18.9,77.7)
Indian Tamil		-175.8 (-269.1, -82.4) ***	-167.9 (-284.3, -51.5) **
Muslims and others		32.9 (-3.9,69.9)	33.8 (-6.9,74.7)
Sector			
Urban			1.00
Rural			2.2 (-32.7,37.2)
Estate			-1.69 (-86.0,82.6)

	Model 1	Model 2	Model 3
Variables	**Coef. (95 per cent CI)**	**Coef. (95 per cent CI)**	**Coef. (95 per cent CI)**
Province			1.00
Western			
Central			-4.8 (-50.6,40.9)
Southern			16.7 (-28.4,61.9)
Northern			89.6 (25.3,153.9) ***
Eastern			-18.0 (-65.4,29.3)
North-Western			23.7 (-25.6,54.3)
North-Central			-23.6 (-78.3,30.9)
Uva			-29.8 (-78.5,18.7)
Sabaragamuwa			-69.0 (-121.4, -16.6) **
Community poverty			
Low			1.00
High			17.1 (-16.12,50.3)
Community Education			
Low			1.00
High			25.2 (-3.3,53.9)
R2	0.07	0.08	0.10
Constant	205.0	385.7	458.4

*P < 0.05 **P<0.01*** P<0.00

The normality of the final model was tested by plotting a standardised normal probability (P-P) plot. The residuals are close to being normally distributed (Appendix C).

The homogeneity of variance of the residuals was also tested in the final model using a scatter graph featuring residuals versus fitted (predicted) values. It showed that the pattern of the data points lies on or close to the reference line with a residual of at= 0. There is no evidence of heteroscedasticity.

4.9.2 Results of the multivariate logistic regression

Table 4.6 shows the results of a series of adjusted logistic regression models fitted to the DHS data. It is problematic to compare odds ratios across models with different independent variables in the sample as it reflects the degree of unobserved heterogeneity in the model (Mood, 2010). Hence, there was no intention to compare models using odds ratios.

In Model 1, maternal depletion variables including BMI, height, antenatal care visits, birth intervals, consuming IFA, and the sex of the infants have the largest effect in explaining the prevalence of LBW. A negative relationship was found between height and low birth weight. Mothers classified as lower BMI were more likely to deliver low birth weight babies than mothers with normal BMI levels (AOR = 1.72; 95 per cent CI: [1.40,2.12]). This means women who have shorter stature are more likely to deliver LBW babies. The odds of having LBW babies among mothers who did not consume IFA was 50 per cent (AOR=1.50, 95 per cent CI: [1.06, 2.11]) higher odds than the mothers who consumed IFA after controlling other factors. Finally, a girl baby was 39 per cent more likely to be of LBW (AOR = 1.39, CI: [1.19, 1.63]) than was a boy baby. The BMI squared value was not significant in the model. Hence, it is removed from the model.

In Model 2, all the maternal depletion factors remained significant except for the consumption of IFA. The education level was significant in the model, for mothers who have passed GCE advanced level had lower odds compared to mothers who completed primary education (AOR=0.54, 95 per cent CI: [0.67,1.38]). Further, being an Indian Tamil woman was significantly associated with LBW compared to Sinhalese (AOR =1.43, CI: [1.03, 2.07]). The household wealth index seemed to be a strong predictor of LBW, as children in the highest household quintile, had lower odds of LBW compared with those in the lowest quintile (AOR = 0.56; 95 per cent CI: [0.42,0.74]).

The final model included geographic factors including residential sectors and provinces in addition to maternal and socioeconomic variables. IFA variable was removed from the final model due to the insignificant value. Maternal factors remained statistically significant, while mothers who completed GCE Advanced Level had 40 per cent less likely to have had a low birth weight baby compared to mothers who completed primary education (AOR = 0.60; 95 per cent CI:[0.65,1.34]). The odds of low birth weight among Indian Tamil mothers were 1.62 times higher than those of other mothers belonging to other ethnicities (AOR= 1.62; 95 per cent CI: [0.95,2.70]). Mothers lived in the Sabaragamuwa Province had 1.35 times higher odds of LBW than those who reside in the Western Province (AOR = 1.35; 95 per cent CI: [1.03-1.80]). Similar to the multivariate linear model, Northern Province mothers had lower odds of having low birth weight babies compared to the Western Province mothers (AOR = 0.61; 95 per cent CI: [0.43,0.85]). In the final model, I tested interactions for wealth groups and ethnicity. The relationship was found to be statistically insignificant.

For comparison purposes with the standard low birth weight indicator (less than 2500 grams), this study generated a separate binary variable (normal birth weight ≥ 2,500g, coded 0) or LBW low birth weight (birth weight <2500g, coded as 1) and applied only to the final model (model 3). It could appear that results are slightly different from the present model (Appendix D).

Table 4.6 Results of the multiple logistic regression-adjusted odds ratios (95% CI) of maternal, socioeconomic and geographic factors associated with LBW

Variables	**Model 1**	**Model 2**	**Model 3**
	AOR (95 per cent CI)	**AOR (95 per cent CI)**	**AOR (95 per cent CI)**
Maternal Body Mass Index			
BMI < 18.5	1.72 (1.40, 2.12) ***	1.59 (1.28,1.94) ***	1.60 (1.30,1.96) ***
BMI 18.5-24.9	1.00	1.00	1.00
BMI 25.0-29.9	0.81 (0.68, 0.96) **	0.86 (0.72,1.03)**	0.89 (0.75,1.06)**
BMI >= 30.0	0.72 (0.55,0.93) **	0.79 (0.60,1.03)*	0.76 (0.58,0.99)
Maternal height (cm)			
Short <=145 cm	1.85 (1.46,2.34) ***	1.76 (1.33,2.15) ***	1.74 (1.35,2.12) ***
Average 145.1-155 cm	1.00	1.00	1.00
Tall 155.1 & over	0.58 (0.49,0.68) ***	0.62 (0.52,.0.72) ***	0.62 (0.52,0.71) ***
Number of anc visits			
Below 3 times	1.16 (0.87,1.55)	1.25 (0.94,1.66)	1.06 (0.98,1.26)
3-5 times	1.73 (1.41,2.12) ***	1.78 (1.44,2.19) ***	1.74 (1.41,2.15) ***
6-10 times	1.00	1.00	1.00
11 or more	0.87 (0.54,1.19)	0.79 (0.53,1.18)	0.78 (0.52,1.16)

Variables	Model 1	Model 2	Model 3
	AOR (95 per cent CI)	AOR (95 per cent CI)	AOR (95 per cent CI)
Birth Interval			
First birth	1.00	1.00	1.00
< 24 months	0.68 (0.47,0.98)*	0.63 (0.44,0.91) *	0.62 (0.43,0.89) *
24-47 months	0.58 (0.46,0.73)***	0.53 (0.44,0.65) ***	0.55 (0.44,0.68) ***
48 months or more	0.84 (0.72,0.97)**	0.76 (0.66,0.89) **	0.71 (0.55,0.91) **
Consumption of IFA			
Received and consumed	1.00	1.00	1.00
Not received and not consumed	1.50 (1.06,2.11) *	1.43 (1.09,2.02)	
Sex of a child			
Male	1.00	1.00	1.00
Female	1.39 (1.19,1.63) ***	1.40 (1.18,1.54) ***	1.38(1.18,1.57) ***
Educational category			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		0.75 (0.82,2.11)	0.80 (0.60,1.08)
Advanced Level		0.54 (0.67,1.38) ***	0.60 (0.65,1.34) **

Variables	Model 1	Model 2	Model 3
	AOR (95 per cent CI)	AOR (95 per cent CI)	AOR (95 per cent CI)
Degree and above		0.75 (0.48,1.13)	0.85 (0.62,1.28)
Wealth index			
Lowest		1.00	1.00
Second		0.85 (0.69,1.03)	0.80 (0.64,0.99) *
Middle		0.86 (0.70,1.06) *	0.79 (0.63,0.99) *
Fourth		0.73 (0.58,0.91) *	0.69 (0.54,0.88) **
Highest		0.56 (0.42,0.74) ***	0.53 (0.39,0.72) ***
Ethnicity			
Sinhala		1.00	1.00
Sri Lankan Tamil		0.75 (0.61,0.93)	0.90 (0.66,1.23)
Indian Tamil		1. 43 (1.03,2.07) *	1.62 (0.95,2.70) *
Muslims and others		0.72 (0.56,0.91) *	0.73 (0.54,0.99)
Sector			
Urban			1.00
Rural			0.94 (0.75,1.18)

Variables	Model 1	Model 2	Model 3
	AOR (95 per cent CI)	**AOR (95 per cent CI)**	**AOR (95 per cent CI)**
Estate			0.94 (0.60,1.45)
Province			
Western			1.00
Central			1.12 (0.86,1.46)
Southern			1.14 (0.87,1.49)
Northern			0.61 (0.43,0.85) *
Eastern			1.03 (0.78,1.36)
North-Western			1.20 (0.92,1.56)
North-Central			0.97 (0.70,1.35)
Uva			0.99 (0.72,1.37)
Sabaragamuwa			1.35 (1.03,1.80) **

***P < 0.05 **P<0.01**P<0**

4.10 Predicted probabilities of low birth weight for selected women

This study further calculated predicted probabilities for low birth weight using the final multivariate logistic regression model estimates for different targeted mothers in the sample. Prediction at the means is more applicable continuous covariates, however, it is not meaningful in the presence of dichotomous covariates and could create substantial errors when confounders are strongly associated with the outcome (Muller and MacLehose, 2014). When calculating predicted probabilities for dichotomous confounders, marginal standardisation is the appropriate method for making an inference to the overall population from which the study sample was drawn (Williams, 2012). In this study, we use the final model to predict the probability of low birth weight for certain hypothetical women who have characteristics representative of specific groups of real women in Sri Lanka.

As Table 4.7 illustrates, the first representative woman represents a normal (average) woman, who is in the middle wealth category, passed GCE Advanced levels, settled in the rural sector and belong to the Sinhalese ethnicity, and lives in the Southern Province. She has a normal BMI level with an average height; made 6-10 times antenatal care visits when she was pregnant and gave birth to a baby girl with a preceding birth interval of 48 and over months. This woman has a predicted probability of low birth weight of 0.20 (20 per cent), slightly higher than the overall Sri Lankan low birth weight rate reported as 16.9 per cent in this study.

The second representative woman has background characteristics such as poor education (primary level), is in the poorest wealth category, and is an Indian Tamil living in the estate sector in Sabaragamuwa district. This woman is an underweight woman, with a short stature and she was only able to make less than three antenatal visits and delivered a baby girl with a short birth interval (<24 months). This baby girl has a predicted probability of 0.67 (67 per cent) of being low birth weight. This indicates that Indian Tamil mothers in the estate sector are highly likely to have low birth weight babies, even though low birth weight is relatively rare in Sri Lanka as a whole.

An overweight and short her by her appearance, who is well educated to degree level and in the highest wealth category is the third representative women. She is settled in the urban sector and belongs to the Sinhala ethnicity. She lives in the urban sector in the Western Province, Sri Lanka. She had frequent access to antenatal care during pregnancy and delivered a son as her first child. This woman has a predicted probability of 0.16 (0.16 per cent) of having a low birth weight infant.

It can be concluded that socially and economically disadvantaged women with poor educational level and wealth status, and especially women belonging to the Indian Tamil ethnicity living in the estate sector in provinces such as Sabaragamuwa, have a high predicted probability of delivering a low birth weight child. Maternal depletion factors play a crucial role in predicting low birth weight. For example, women with poor nutrition indicators such as low BMI and short stature can have a low nutritional reserve at the onset of pregnancy compared to well-nourished women. Their micronutrient supply can be inadequate, especially if they have not received free iron or folic acid supplements from antenatal care clinics due to few visits. Short birth intervals increase the risk of maternal depletion, which in turn affects the growth of a foetus.

Table 4.7 Results of the predicted probabilities for selected women

Covariates	Women 1	Women 2	Women 3
Maternal Body Mass Index	18.5-24.9	<18.5	25-29.9
Maternal height (cm)	145.1-155 cm	Short <=145 cm	Short <=145 cm
Number of anc visits	6-10 times	Below 3 times	11 and over
Preceding birth interval	48 and over	<24 months	48 and over
Sex of a child	Girl	Girl	Boy
Educational category	G.C.E (A/L)	Up to grade 5	Degree and above
Wealth index	Middle	Lowest	Highest
Ethnicity	Sinhalese	Indian Tamil	Sinhalese
Sector	Rural	Estate	Urban
Province	Southern	Sabaragamuwa	Western
Intercept	-0.9579788	-0.9579788	-0.9579788
Predicted Probability	**0.201**	**0.677**	**0.167**

4.11 Results of the multilevel Analysis

4.11.1 Selecting mother as a second level in the multilevel modelling analysis

Based on the three-level nesting structure, we had a choice as to whether the mother or the household should be selected as the second level within which children were nested. The data consist of 7,713 children to 6,810 mothers in 6,723 households, nested within 2,321 clusters. Of the 6,723 households, only 98 (1.27 per cent) had two or more children. This means that it is unlikely that we shall be able to obtain reliable estimates of both mother and household level variance components. However, 903 mothers had more than one child and these mothers being grouped within communities (primary sampling units or clusters). Therefore, we examined the variation in LBW at three levels: child, mother and community. Two reasons favour using mother rather than household as the second level. First, children derive genetic influences from their mothers and environmental influences from their households. For birth weight, we consider that the genetic influences probably outweigh the environmental ones, and therefore favour choosing the mother as second level. Second, we estimated variance components models using mother and household as the second level. The results (Table 4.8) reveal that the ICC at the mother level is slightly higher when the mother is used as the second level than when the household is used.

Due to the hierarchical nature of the data with some mothers having more than one child (903 mothers), and these mothers being grouped within communities (primary sampling units or clusters), we examined the variation in LBW at three levels: child, mother and community, using the same series of models, but taking account of the fact that some mothers have more than one child, and mothers are clustered within communities.

Table 4.8 Comparison of mother and household as level 2 unit for the multilevel analysis

Level 2 unit	**Log-likelihood**	**Random-effect parameter: variance at each level**	**Intraclass correlation coefficient**
Household	-3466.23	Cluster level: 0.16 Cluster/household level: 2.00	Cluster level: 0.013 Cluster/household level: 0.556
Mother	-3455.58	Cluster level: 0.24 Cluster/mother level: 2.30	Cluster level: 0.006 Cluster/mother level: 0.61

4.11.2 Moving to a two-level model from three-level model

After choosing mother as an appropriate second - level unit, a null model (without covariates) was fitted to estimate the variance at each level. There was a variation of low birth weight at all levels of the hierarchy (children, mothers and communities), but the variation at the community level was small once the variation at the mother level was considered. According to the results (Table 4.9), a variance of 2.30 was attributed to mothers with an ICC of 0.61, whereas the ICC at the community level was very small, suggesting that there is no greater correlation between the weights of babies in the same community than between babies selected at random.

Table 4.9 Results of three-level variance components model (child, maternal and community level)

Effect	Estimate	95% confidence interval
Intercept β_0	-2.77	-3.10, -2.44
Community-level variance	0.24	0.005, 10.32
Mother-level variance	2.30	1.92, 2.76
Log Likelihood	-3455.583	
ICC at community level	0.006	0.00, 0.93
ICC at mother level	0.61	0.54, 0.70

In the light of these results, this study fitted a two-level mixed effect logistic regression model using individual (children) as a first level and mothers as a second level, ignoring the community (cluster) level. As noted elsewhere, ignoring a level which has a relatively small variance would not cause any harm as the estimates of the fixed parameters will remain unchanged (Vaezghasemi et al., 2016; Van den Noortgate et al., 2005).

4.11.3 Results of the two-level mixed effect logistic regression model

We then added the covariates described in Model 3 to the two-level model. Consumption of iron and folic acid and residential sector variables were removed from the model, as it was not significant in the previous final multivariate model. The results (Table 4.10) show that variation in low birth weight at the mother level remained important level (τ^2 = 2.38). The ICC at the mother level has declined slightly compared with the null model but is still substantial.

As shown in the results (Table 4.10), results were similar to the fixed effect logistic regression final model. Maternal body mass index, maternal height, preceding birth interval, number of antenatal care visits and the sex of the child, maternal education, wealth quintile, ethnicity and province were independently associated with low birth weight after adjusting for maternal, socioeconomic and geographic factors. Being a female child was found to be a risk factor for low birth weight (adjusted odds ratio (AOR= 1.51, 95 per cent CI: [1.22, 1.86]). Mothers who had passed GCE- A/L were less likely to have low birth weight children than less well-educated women (AOR = 0.34, 95 per cent CI:[0.19,0.60]), as were women in the highest and second highest wealth quintiles compared with less wealthy women (highest wealth quintile AOR = 0.42, 95 per cent CI: 0.26-0.68). Indian Tamil mothers were more likely to have low birth weight babies than mothers belonging to other ethnicities or residing in other areas (AOR = 1.79, 95 per cent CI: [0.94,3.18]).

Low birth weight was more common in Sabaragamuwa Province (AOR = 1.63; 95 per cent CI 1.05, 2.52) than the Western Province. The random effect was important: observations at the maternal level were highly correlated, with an intra-class correlation coefficient of 0.63. This reflects the impact of unmeasured factors such as genetic and environmental factors that were not explained in this model. In the two-level variance components model the random intercept at the mother level was 2.38, very similar to its value in the three-level variance components model (Table 4.10).

Table 4.10 Fixed and random effects for children and mother level for low birth weight children controlling for maternal depletion, socioeconomic and geographic factors

Covariates or factors	Odds ratios (95 per cent confidence intervals)
Maternal Body Mass Index	
BMI < 18.5	2.03 (1.39,2.88) ***
BMI 18.5-24.9	1.00
BMI 25.0-29.9	0.76 (0.59,0.95) **
BMI >= 30.0	0.63 (0.42,0.92) **
Maternal height (cm)	
Short <=145 cm	2.45 (1.68,3.99) ***
Average 145.1-155 cm	1.00
Tall 155.1 & over	0.45 (0.34,0.59) ***
Number of anc visits	
Below 3 times	1.15 (0.88,1.51)
3-5 times	2.46 (1.73,3.50)
6-10 times	1.00
11 or more	0.65 (0.36,1.19) **
Preceding birth interval	
First birth	1.00
< 24 months	0.50 (0.27,0.78) **
24-47 months	0.43 (0.31,0.58) ***
48 months or more	0.66 (0.37,0.81) **
Sex of a child	

Covariates or factors	Odds ratios (95 per cent confidence intervals)
Male	1.00
Female	1.51 (1.22,1.86) ***
Maternal education	
Up to grade 5	1.00
Grade 6 to Ordinary Level	0.59 (0.37,0.96)
Advanced Level	0.34 (0.19,0.60) ***
Degree and above	0.63 (0.31,1.21)
Wealth index	
Lowest	1.00
Second	0.78 (0.55,1.10)
Middle	0.84 (0.58,1.21)
Fourth	0.58 (0.38,0.86) **
Highest	0.42 (0.26,0.68) ***
Ethnicity	
Sinhalese	1.00
Sri Lankan Tamil	0.73 (0.56,1.42)
Indian Tamil	1.79 (0.94,3.18) *
Muslims and other ethnicities	0.56 (0.38,0.84)
Province	
Western	1.00
Central	1.22 (0.79,1.87)
Southern	1.09 (0.70,1.68)
Northern	0.62 (0.39,1.05)
Eastern	1.17 (0.74,1.83)
North-Western	1.35 (0.86,2.09)
North-Central	0.96 (0.56,1.62)
Uva	0.98 (0.64,1.66)

Covariates or factors	Odds ratios (95 per cent confidence intervals)
Sabaragamuwa	1.63 (1.05,2.52) **
Mother-level variance (CI, standard error)	2.38 (1.92,2.95) (0.2259)
Intraclass correlation coefficient (CI, standard error)	0.63 (0.52,0.72) (0.259)
Log likelihood	-3190.92
Akaike information criterion (AIC)	6449.85
Bayes information criterion (BIC)	6685.42

*P < 0.05 **P<0.01*** P<0.001

4.12 Summary of key findings

This section summarizes the results of the first analysis; the findings are discussed in Chapter 4 of this thesis.

- Results from multiple linear and logistic regression analyses suggested that maternal variables such as BMI, maternal height, preceding birth interval, intake of micronutrients (IFA-iron and folic acid), the number of antenatal visits and child's sex status have a significant influence on birth weight status.
- In terms of the maternal depletion factors, maternal BMI and height were strongly associated with low birth weight; mothers with lower BMI and short in height were more likely to have LBW babies than those with normal BMI and height.
- Considering the socioeconomic factors, mothers who completed GCE advanced level had lower odds of having LBW babies compared to mothers who completed primary education who was set as the reference category. Children whose mothers from the richest households were less likely to have low birth weight children, than mothers in poor wealth quintiles.
- Results showed that socioeconomic inequalities exist; negative concentration indices suggested a relatively higher concentration of LBW in poor households, particularly those from Indian Tamil communities living in the estate sector.
- The random intercept models confirmed substantial unobserved variation in LBW outcomes at the mother level.

The next chapter explores the determinates of child undernutrition outcomes in Sri Lanka and it will be further investigated the role of birth weight in determining undernutrition outcomes in Sri Lanka.

4.13 Strengths and limitations

The strength of this study is that it covers the whole island including war-affected districts for the first time in the DHS history in Sri Lanka. The use of birth weight data collected from health records is another strength of this study. However, this data may be biased due to rounding errors or other errors related to weighing instruments. Unlike other DHSs, there was no information on maternal perception of the size of the baby at the time of birth in Sri Lanka – the availability of such information could have helped to validate the recorded birth weight data (Channon, 2011). Sri Lanka has adopted the WHO standard cut-off (less than 2500 g) to interpret the low birth weight prevalence. Some studies, however, have argued that the mean low birth weight in Sri Lanka is significantly lower than the WHO standard (Abeyagunawardena et al., 2018; Perera et al., 2013). Therefore, using a standard cut-off could be identified as a limitation of this study.

DHS has no data on gestational weight gain and pre-pregnancy weight, although both are deemed to be critically important predictors of low birth weight. Hence, this study used BMI values reported during the interview assuming that the actual change is insignificant. This may have influenced the outcome to some extent. Maternal height is a stable anthropometric indicator to measure maternal nutritional level. However, maternal weight is subject to considerable change after pregnancy. Since the analysis is based on data for the 5 years preceding the survey, this could have influenced the actual outcome to some degree. Therefore, it is recommended that future studies include recent anthropometric measures and pre-gestational BMI to examine if there is a relationship with birth weight.

DHS surveys are only limited to health indicators which can be measured with relatively few questions. There are no satisfactory questions on genetic factors, which is a potential limitation of the study. However, this study used maternal height as an indirect proxy to capture genetic factors. There is a limited number of questions capturing maternal depletion and data on health services is limited. For example, there is no information on distance to access health services, maternal anaemic status and quality of maternal care in determining low birth weight.

Finally, The DHS is a cross-sectional study; hence, no causal relationship can be established between the explanatory and response variables.

Chapter 5 Understanding inequalities in child undernutrition outcomes in Sri Lanka

5.1 Abstract

Background: Child nutrition outcomes have not shown any significant improvement over a decade (2006-2016) in Sri Lanka, despite improvements in low infant, under-five and maternal mortality rates.

Aims: To examine the determinants of child nutritional outcomes in Sri Lanka and to assess the extent of inequalities in these outcomes by socioeconomic and geographic factors.

Methods: Using the 2016 Sri Lankan DHS data, fixed and random effect logistic regression models were applied to examine the association between selected maternal social, bio-behavioural factors, childbirth and post-birth factors, household and community factors, and undernutrition outcomes (stunting, wasting and underweight) in young children. Concentration curves and concentration indices were obtained to examine the extent of socioeconomic inequalities in child nutrition outcomes. We hypothesised that children living in poor households and born to Indian Tamil mothers in the estate sector have higher risks of stunting than their counterparts in other sectors.

Participants: The analysis sample consisted of 7,259 children aged 6-59 months, who had reported their complete anthropometric measurements.

Results: Overall, about 18.2 per cent of the children had stunting, 14.5 per cent had wasting and, 20.7 per cent had underweight. Child's age, sex, birth interval, birth weight, maternal BMI, maternal stature, ethnicity, wealth quintile, and province had a significant association with stunting. Similar effects were observed for wasting, except for maternal stature, wealth and province. However, child morbidity and maternal education were found significant for wasting outcome. For child underweight, similar significant effects were observed, however, ethnicity was not significant. Findings demonstrated evidence of socioeconomic inequalities; stunting, wasting and underweight are more concentrated among the poor when compared to well-off households. Further, the analysis of random effects confirmed that the variance in undernutrition outcomes between communities was less, compared to the variance attributed to differences between households within the community.

Conclusion: Maternal BMI and stature and low birth weight were the most significant factors associated with stunting but not wasting, suggesting an intergenerational link underlying maternal and child health. The findings direct the urgent need to design interventions aimed at improving nutrition throughout the life course to break the cycle of undernutrition in Sri Lanka.

Key messages

- Child stunting, wasting and underweight are more concentrated among the poor when compared to well-off households.
- Undernutrition inequalities are higher among child stunting, followed by the underweight.
- Child, maternal and household-level characteristics are more important than community- level factors in explaining child undernutrition.

5.2 Introduction

Child undernutrition, measured in terms of stunting, wasting and underweight, manifests itself as one of the major contributors to child mortality and morbidity in developing countries. It is estimated that more than 150 million children worldwide are stunted while 45 per cent of deaths among children aged under five years in low and middle income countries (LMICs) are linked to undernutrition (UNICEF et al., 2017). The levels and patterns of child nutrition at the global level and in Asian countries are discussed elsewhere (see Chapter 2, p. 25-27).

Child undernutrition remains one of the critical public health challenges in Sri Lanka. The child undernutrition problem is characterised by adverse growth outcomes over the last two decades, and the level of stunting and underweight across different social groups shows wide variations with substantial inequalities. For a country with low mortality, universal access to free maternal and child health services and no significant food shortages, child undernutrition in Sri Lanka remains paradoxical and an unresolved public health crisis. This study aims to examine the bio-demographic, socioeconomic and geographic factors associated with undernutrition in children aged under five years and also to examine underlying socioeconomic inequalities associated with child undernutrition outcomes in Sri Lanka with a focus on its differentials by ethnic groups and geographic provinces.

5.2.1 Stunting

Among different forms of malnutrition, child stunting (i.e. low height-for-age) defined as a height-for-age *z*-scores (HAZ) are below minus two standard deviations (-2SD) from the median of the

World Health Organization (WHO) child growth standard (World Health Organization, 2006). Stunting occurs as a result of the cumulative process of growth retardation, which not only depends on inadequate nutrition, but also associated with a number of factors including recurrent infections such as fever, diarrhoea and acute respiratory infections (Black et al., 2008; Ortiz et al., 2013). Among LMICs, Asia and Africa hold the largest share of all forms of child malnutrition with 56 per cent of all stunted children living in Asia, while more than one third (38 per cent) are in Africa in 2016 (UNICEF et al., 2017).

Additionally, maternal characteristics such as maternal body mass index (BMI) levels, breastfeeding and complementary feeding behaviours are associated with the risk of child malnutrition (Batiro et al., 2017; Beal et al., 2018). Birth weight is also found to be a main risk factor for child stunting (Aryastami et al., 2017; Rahman et al., 2016). Alongside maternal factors, household and environmental conditions such as inadequate sanitation, untreated drinking water, inadequate local waste disposal, unimproved latrines, dirt floors in the home, and poor-quality cooking fuels are associated with an elevated risk of childhood stunting (Rah et al., 2015; Vilcins et al., 2018).

Low socioeconomic status is important in predicting child stunting in different social contexts. For example, maternal wealth and education are significantly associated with stunting (Bbaale, 2014; Makoka and Masibo, 2015). There is also evidence to suggest that children living in poor households are more likely to be stunted than those from richer households (Kismul et al., 2017; Van de Poel et al., 2008; Zere and McIntyre, 2003).

Stunting propensity is significantly higher in early childhood (6-24 months), leading to the development of permanent deficiencies towards adulthood (Derso et al., 2017). These include both short-term and long-term consequences. The short-term consequences include poor physical and cognitive development and decreased immunity. The long-term consequences include cognitive disability in later adult life, reduced school performance, and lower work capacity that hinders future economic productivity (Bhutta, 2017; Martins et al., 2011; McGovern et al., 2017; UNICEF et al., 2017; Woldehanna et al., 2017). Research into the fetal origins of adult diseases has provided evidence that the nutrition in fetal life influences adult diseases such as coronary heart disease, hypertension, obesity, and insulin resistance (Barker, 1994; Barker, 2012; Calkins and Devaskar, 2011).

5.2.2 Wasting

Child wasting (i.e. low weight-for-height) is defined as characteristic of children whose weight-for-height *z*-scores (WHZ) are below minus two standard deviations (-2SD) from the median of the WHO child growth standard. Wasting is considered to be a better predictor of child mortality than stunting (Ortiz *et al*., 2013), and an indicator of acute undernutrition associated with weakened immunity, with a risk of long-term impairment and potential life threats when wasting becomes severe (severe wasting is defined as a WHZ more than three standard deviations below the mean of the WHO growth standard (UNICEF *et al*., 2017). In 2017, about 51 million children worldwide were reported to be nutritionally wasted and, among these, South Asia shares a substantial burden of the proportion of wasted children (nearly 26.9 per cent) compared to other regions in the world (UNICEF *et al*., 2017). Child wasting is rarely associated with one factor alone; it is often interlinked with poverty, diseases and poor diet (Darteh et al., 2017; Derso et al., 2017). However, irrespective of the context, almost every study highlights the fact that severely wasted children are at increased risk of life-threatening infections (Walson and Berkley, 2018).

5.2.3 Underweight

Underweight (i.e. low weight-for-age) children are those with a weight-for-age *z*-scores (WAZ) are below minus two standard deviations (-2SD) from the median of the WHO child growth standard. This is another important anthropometric measure for evaluating child undernutrition (Adhikari et al., 2017; Mukabutera et al., 2016). Worldwide, proportions of children underweight have fallen, but there remain an estimated 192 million severely or moderately underweight children at the global level, mainly in Asia and Africa (Abarca-Gómez et al., 2017). Age of the child, birth weight, prolonged breastfeeding maternal height, education, diet, household living conditions including access to sanitation, personal hygiene such as recent diarrhoea episodes and lack of access to safe drinking water are highlighted as some of the major risk factors associated with underweight across regions (Adhikari et al., 2017; Alasfoor et al., 2007; Griffiths et al., 2004).

Despite improvements in child and maternal health and life expectancy indicators, Sri Lanka has not made progress in reducing child undernutrition as much has been expected. For example, the recent Demographic and Health Survey in 2016 reported the percentages of children stunted, wasted and underweight to be 17 per cent, 15 per cent, and 21 per cent respectively. These percentages have stagnated since 2006 (Department of Census and Statistics, 2017).

5.2.4 Child feeding practices on child undernutrition outcomes

Proper infant and young child feeding (IYCF) practices are pivotal to prevent malnutrition within the critical period of the first two years of life (World Health Organization, 2009). According to the WHO conceptual framework, inadequate IYCF practices, poor-quality food, low dietary diversity and intake of food, infrequent, and insufficient frequency of feeding are mainly responsible for childhood stunting (Saha et al., 2008; World Health Organization, 2009). Having proper IYCF practices could help children catch up within the first two years of life and reduce the risk of child morbidity and mortality.

WHO recommends using core infant and young child feeding (IYCF) indicators: early initiation of breastfeeding; exclusive breastfeeding for six months; continued breastfeeding at one year; minimum dietary diversity; minimum meal frequency; and consumption of iron-rich or iron-fortified foods. Exclusive breastfeeding is defined as the infant receiving only breast milk up to the first six months (World Health Organization, 2019b). After being exclusively breastfed for the first six months of life, solid foods/complementary foods should be introduced two to three times a day, whilst the child continues to be breastfed regularly (World Health Organization, 2018b). A considerable number of studies showed that exclusive breastfeeding is one of the crucial interventions on child growth and survival (Khan and Islam, 2017; World Health Organization, 2019b). However, various studies report that breastfeeding beyond the age of twelve months is associated with poor nutritional status and poor health status of the children (Cetthakrikul et al., 2018; Syeda et al., 2020).

Whilst WHO recommends continued breastfeeding from 6 months up to 2 years of age, a systematic review on the global prevalence of breastfeeding up to two years of age or beyond and its effect on child growth, found that South Asia has the highest prolonged breastfeeding beyond the age of twelve months, though there was no association between continued breastfeeding and child development (Delgado and Matijasevich, 2013). This study concluded the requirement of further research evidence on the effects of breastfeeding up to two years of age or beyond on child growth. Some studies reported that children who are breastfed beyond the age of twelve months in poor wealth groups are likely to have poor nutritional status, particularly stunting (Cetthakrikul et al., 2018).

The reasons for an inverse relationship between the effect of long-term breastfeeding and child growth are explored in some settings (Martin, 2001; Poton et al., 2018). The differentials in food consumption between breastfed and weaned children during the onset of complementary feeding found as one reason. Mothers who believe that breastmilk would be the best source of nutrition for their child may not have provided the required Vitamins. This also reflects poor access to nutritious food; thus, the mother completely depends on breast milk as the predominant source for thriving the baby, which would be inadequate to meet the nutritional needs of the child. On the other hand, nutritional components in breast milk decrease over time from the time the child is born (Ballard and Morrow, 2013).

It has been recognised that reverse causality could be another possible explanation for the longer duration of breastfeeding and its association with infant growth size (Kramer et al., 2011). According to the evidence from Senegal (Simondon and Simondon, 1998) and Peru (Marquis et al., 1997), potential reverse causality between infant growth and breastfeeding duration could be varying according to the culture, setting and time (Kramer et al., 2011). In the developing country settings, where high prevalence of undernutrition persists, breastfeeding may be encouraged as a way of complimenting the perception of small infant size, whereas, in developed settings,the small size of infants would encourage mothers to provide an adequate source of nutrients for her infants by providing weaning and complementary feeding.

Despite the exclusive breastfeeding for infants, it has been well documented that the other IYCF practices such as minimum Dietary diversity, minimum meal frequency during the critical window (6 to 24 months) period have a significant impact on linear growth faltering of children. (Frempong and Annim, 2017; Mya et al., 2019). It has been evidenced from various contexts that inadequate complementary feeding practices which include the early introduction of complementary foods, lack of consuming diverse foods and insufficient feeding frequency are significantly associated with a reduction of stunting, wasting and underweight in children. A study conducted using DHS data from 14 LMICs demonstrated significant associations between minimum acceptable diet and dietary diversity with reduced risk of stunting and underweight (Marriott et al., 2012). Likewise, dietary diversity was found strongly associated with height-for-age Z-scores (HAZ) for children 6-23 months in another study that investigated the DHS data from 11 countries (Arimond and Ruel, 2004). In contrast, some studies agreed that dietary diversity was only associated with chronic malnutrition and not with wasting which reflects the short-term acute malnutrition (Khamis et al., 2019). Nevertheless, poor dietary diversity indicators reflect household food insecurity and inadequacy of dietary intake which have been identified as the underlying causes for child nutrition in the UNICEF conceptual framework (UNICEF, 2012).

The lack of progress in reducing child undernutrition rates in Sri Lanka for the past decades has led child feeding programmes to become an integral feature of addressing the child undernutrition problem in Sri Lanka. For this reason, the analytical framework used in this study includes child dietary practices. Sri Lanka reports the highest exclusive breastfeeding rate for South Asia (Agampodi et al., 2009) and also recorded the highest performance in IYCF practices compared to the other South Asian countries (World Health Organization, 2017a). The success of the highest exclusive breastfeeding highlights the role of Public Health Midwives in improving breastfeeding practices in Lanka. A small number of studies assessed the dietary diversity and associated factors in Sri Lanka. Socioeconomic disparities in dietary diversity were highlighted, children from the poorest households particularly in the estate sector are shown poor IYCF practices (Department of Census and Statistics, 2017). This may be due to reasons such as lack of affordability and access to food (World Health Organization, 2017a). Further, lower maternal education, shorter maternal height, lack of postnatal visits, unsatisfactory exposure to media and acute respiratory infections are also shown as other determinants of inadequate complementary feeding practices (Senarath et al., 2012). Diversity of food has been assessed and it is found a heavy dependency on staple food such as rice, while consumption of flesh foods, dairy, fruit and vegetables is low (Jayawardena et al., 2013). Despite small-scale studies conducted in a specific setting (districts etc), there is a dearth of investigating the effects of IYCF indicators on child undernutrition in Sri Lanka. This study uses some of the IYCF indicators for children aged 6-23 months to explore the relationship between IYCF practices and child nutritional status.

5.2.5 Child immunisation on child undernutrition outcomes

Immunisation unarguably helps to reduce the incidence of several preventable diseases of childhood. Malnourished children are at an elevated risk of infectious morbidity and mortality compared to well-nourished children and therefore they would benefit from immunisation even more than well-nourished children (Prendergast, 2015). It has been reported that there can exist a vicious cycle of infection and malnutrition, malnutrition could increase the risk of infection, children even could die from the infection. On the other hand, infection also contributes to malnutrition, where immunisation helps to break this vicious cycle (Prendergast, 2015; Walson and Berkley, 2018). A study carried out using DHS data from 16 countries found that child underweight was associated with incomplete vaccination in countries including Angola, Chad, and Guatemala. Likewise, child stunting was significantly observed in incomplete vaccination in Angola, Bangladesh, Chad, and Guatemala, and wasting in Angola, Chad, Kenya, and Myanmar (Solis-Soto et al., 2020). However, contradictory results were also observed from clinical trials and observational studies in England and France which have been reported a negligible effect on malnutrition from vaccine response (Savy et al., 2009).

Reasons for under immunisation are also discussed in the developing country contexts. It is reported that poor access to the immunisation centres, parental knowledge and attitude, conflicting priorities such as incapability to travel long distances, family functions and fear of side effects as barriers for immunisation coverage (Favin et al., 2012). In addition, sick or underweight kids should not be immunised or a child over 12 months is too old to have immunisation are found as misconceptions that are associated with under immunisation in Kenya, Nigeria and Pakistan (Favin et al., 2012). Children who were born at health facilities, the richest wealth status, living in an urban setting, proper ANC during pregnancy period, maternal secondary or higher education status are outlined as the main determinants of immunisation coverage.

Poor health management information system has identified as another barrier for immunisation coverage in South Asia, where the poor-quality outdated data hinders to get the true picture on children who have not been immunised. The timing of the immunisation has been explored in some studies. On-time immunisation is reported to have recovered from stunting during the first five years of age in Africa (Faye et al., 2019). It is also found in India, immunisation before the age of six years is associated with improved later life outcomes such as school attainment and schooling grades in adult life (Nandi et al., 2020). Despite these studies, existing research has not adequately addressed the effect of immunisation on child anthropometric measures, particularly, in South Asian settings.

The national immunisation programme in Sri Lanka was started in 1978. Since then, it has continued to make considerable progress over the past decades. The progress has been commendable in terms of achieving higher immunisation coverage (nearly 100 per cent) and disease control in Sri Lanka. The Sri Lankan National Immunisation Programme adheres to the international guidelines recommended by the WHO (Department of Census and Statistics, 2017). The government of Sri Lanka supplies all childhood immunisation free of charge. Sri Lanka’s immunisation schedule is discussed in Chapter 3 section 3.4.2. The role of public health midwives who are at each MOH has been exemplary for the success of immunisation coverage in Sri Lanka. They are responsible for maintaining proper records of immunisations, in the case if the child is not immunised, PHM should contact the caregivers of children to set an appointment to immunise even via home visits (World Health Organization, 2014b).

The recent DHS data and small-scale studies have reported some disparities in immunisation coverage in terms of residence and access to health care facilities (Department of Census and Statistics, 2017; Lindqvist et al., 2019). For instance, being a female child in urban areas is more likely to be immunised than boys in rural areas. Since there have been no recent studies on early immunisation on child undernutrition in Sri Lanka and the stagnated rates of child undernutrition led present study to examine the relationship between immunisation and child undernutrition indicators as one of the research objectives.

Overall, the achievements in maternal and child health indicators and considerable investment in health and nutrition through policies, programmes and their implementation through government, lack of a consistent improvement in nutrition indices is a cause of concern and has become a puzzle to policymakers in Sri Lanka. Further, child nutritional levels vary within and between different social and economic groups (Jayawardena, 2014; World Health Organization, 2014b). The determinants of child undernutrition in Sri Lanka have been discussed (see Chapter 2, Section 2.6). However, many of these studies were restricted to a specific setting and studies of the prevalence of undernutrition in Sri Lanka as a whole are relatively lacking. The main goal of this analysis is to examine the bio-demographic, socioeconomic and geographic factors associated with undernutrition in children aged under five years, and further to examine how these factors account for potential socioeconomic inequalities in child undernutrition in Sri Lanka.

5.3 Objectives and research hypotheses of the study

The objectives of the study are:

1. To examine the determinants of child undernutrition outcomes in Sri Lanka and to assess the extent of inequalities in child undernutrition by socioeconomic group, residential sector and geographical region'
2. To identify the nature of the association between low birth weight and undernutrition outcomes.
3. To examine the association between child immunisation and child nutritional status.
4. To investigate the association between exclusive breastfeeding and infant and young child feeding practices (IYCF), and child nutritional status.
5. To examine household and community level socioeconomic factors that are associated with child nutritional status.

Research hypotheses

It has been revealed that Sri Lanka is facing a chronic undernutrition challenge which is deeply rooted among the estate Indian Tamil population who are socioeconomically disadvantaged compared to the other socioeconomic groups. As revealed from the previous chapter and a few studies, children born to mothers who are poorly undernourished are likely to be born with birth weight. These poor birth outcomes are concentrated among children born to Indian Tamil mothers who are mostly settled in the estate sector; low birth weight children are likely to suffer from poor undernutrition particularly linear growth problems. Thus, it reflects that the vicious cycle of malnutrition emerges among Indian Tamils in the estate sector. Despite the ethnicity, some studies elaborated that poor nutritional outcomes are associated with poor household income. Few studies assessed the socioeconomic differentials in child undernutrition outcomes and found that poor children are more disadvantageous in terms of long-term growth failures

There were significant disparities persist across income quintiles, for instance, the prevalence of stunting in Nuwara Eliya (where over half the population live on tea estates) is 32.4%, while children in the poorest families across the country are more than twice as likely to be stunted (25%) than those who are better off (Department of Census and Statistics, 2017; European Union, 2018). The present study hypothesises that children living in poor households and born to Indian Tamil mothers in the estate sector have higher risks of stunting than their counterparts in other sectors.

5.4 Data and methods

The analysis uses the data from the Demographic and Health Survey (DHS) conducted in Sri Lanka in 2016. The details of DHS sampling design are discussed in Chapter 3, section 3.2. The Sri Lanka DHS collected data on the nutritional status of children by measuring the height and weight of all children less than five years of age. Data were collected with the aim of calculating three indices: namely, stunting (height-for-age), wasting (weight-for-height) and underweight (weight-for-age).

The DHS collected anthropometric data on 18,302 women aged 15-49 years and 8,193 children who were aged under five years at the time of the survey. However, anthropometric data were available only for 8,104 children in the dataset. No extreme values were reported for the height-for-age, weight-for-age or weight-for- height *z*-scores (that is, values more than six standard deviations from the median). Among 8,104 children, 712 children aged 0-5 months were excluded, which led to a sample of 7,392 children. We further excluded 133 multiple births as these multiples are distributed biologically and socio-demographically similar to singletons. The final sample consisted of 7,259 children aged 6-59 months.

5.4.1 Outcome variables

The nutritional status of children in the survey population is compared with the World Health Organisation (WHO) child growth standards. Stunting, wasting, underweight were identified separately as variables with binary categories. For example, if a child's height-for-age *z*-score was below minus two standard deviations (-2SD) from the median of the WHO standard, he or she was categorised as 'stunted' and given the code 1 for the binary variable denoting stunting. The rest of the children were given the code 0 on this variable. An analogous procedure was used to create two similar variables for identifying wasting and underweight.

5.4.2 Explanatory variables

Explanatory variables used in the analysis are described in Table 5.1.

Table 5.1 Definition and coding of variables for analyses presented in Chapter 5

Variable	Definition and coding
Child factors	
Child’s age in months	Coded as (1) 6-11; (2) 12-24; (3) 25-47; (4) 48-59
Birth weight	Child's birth weight was grouped as (1) <=2.5kg; (0) other
Sex	Coded as (1) male; (2) female
Birth interval	Coded as (1) first birth; (2) less than 24 months; (3) 24-47 months; (4) 48 months and over
Child morbidity status	Considered as (1) had at least diarrhoea or cough or fever; (0) had none
Child immunisation status	Calculated for children aged 12 months and older as (1) fully immunised; (2) partially immunised; (3) none
Infant and young child feeding (IYCF) for children aged 6-23 months	Based on the DHS statistics of the recall of food consumed by the children in the 24 hours preceding the interview, as recorded in the DHS.
Exclusive breastfeeding	Coded as (1) for infants who exclusively received breast milk, 24 hours prior to survey; (0) for those who did not.
Minimum dietary diversity	Coded as (1) child had eaten at least from 4 or more food groups the day before the interview; (0) if less than four food groups were consumed
Minimum meal frequency	Coded as (1) child who had the minimum meal frequency; (0) child did not have the minimum meal frequency
Consumption of iron-rich foods	Coded as (1) child received iron-rich foods; (0) child did not receive iron-rich foods
Current breastfeeding	Coded as (1) currently breastfeeding; (0) not currently breastfeeding
Breastfeeding duration	Coded as (1) less than one year; (2) 2-3 years; (3) over 3 years
Maternal factors	
Maternal age (years)	Coded as <=20, 21-29, 30-34, 35 or more years
Maternal height	Categorised as (1) short (≤ 145 cm); (2) average (145.1-155 cm); (3) tall (> 155.1 cm)

Variable	Definition and coding
Maternal BMI	Coded as (1) low (< 18.5 kg/m^2); (2) normal or healthy weight (18.5-24.9 kg/m^2); (3) overweight; (25 -29.9 kg/m^2); (4) obese (>= 30 kg/m^2)
Marital status	Grouped into 2 categories: (1) married/cohabiting; (2) widowed/divorced/separated
Educational status	Mother's highest level of completed education. Categorised as (1) up to and including grade 5; (2) grade 6 to 0/L (Ordinary Level); (3) passed GCE Advanced Level; (4); Degree and above
Household factors	
Ethnicity	Grouped according to the major ethnic groups: (1) Sinhala; (2) Sri Lankan Tamil; (3) Indian Tamils (4) Muslim, Malay, and Burgher ethnicities
Household wealth index	Quintiles of household wealth, coded as: (1) poorest; (2) poorer; (3) middle; (4) richer; (5) richest
Number of household members	Classified as (1) fewer than five members; (2) 5-7 members; (3) 8 or more members
Household environment and sanitary characteristics	
Source of drinking water	Classified as (1) improved (piped water, protected/semi protected well, tube well, bowser and bottled water); (2) unimproved (unprotected well, river/tank/streams/spring, rainwater, etc.)
Toilet facilities	Classified as (1) improved, if the household had a pit latrine with a slab, septic tank or flush toilet; (2) non-improved, if there was no toilet facility, bucket toilet or an open pit was used.
Use of cooking fuel	Classified as (1) modern energy sources, including electricity, natural gas, biogas and kerosene; (2) traditional fuels, including wood, sawdust, rice husks and charcoal
Ownership of livestock	Categorised as (1) household owns livestock (cattle, chickens, sheep); (2) household does not own livestock
Maternal media exposure	A composite indicator measuring the extent of exposure to all forms of media (newspaper, radio and television), coded as (1) limited; (2) moderate; (3) frequent
Residential factors	
Residential sector	Coded as (1) urban; (2) rural; (3) estate
Geographical province	Nine provinces, coded according to the administrative classification of Sri Lanka
Community factors	Created by aggregating individual level characteristics at the community level and grouped as high and low based on the distribution of the proportions
Community poverty	Classified as (1) low, if the proportion of individuals in the community at least in poorer and poorest wealth quintiles is less than 40 per cent (2) high, if the proportion in community at least in poorer and poorest wealth quintiles is 40 per cent or more
Community maternal education	Classified as (1) low, if the proportion of mothers with at least completed O/L is less than 42 per cent); (2) high, if the proportion of mothers with a least completed O/L is 42 per cent or more

5.4.3 Data analysis

The association between nutritional status and independent variables was explored by undertaking cross-tabulations using the variables described in Table 5.1. A chi-square *p*-value is shown to ascertain whether the difference in characteristics is statistically significant or not. Variables with a *p*-value of less than 0.05 are identified to be significantly associated with a child's stunting, wasting or underweight status. Based on the results of the preliminary analysis, variables that turned out to be statistically significant in the bivariate analysis were included in the multivariate fixed-effects logistic regression model. All explanatory variables were entered simultaneously in the model and variables that are not significant were then left out of the model.

The results of the fixed-effect logistic regression analyses are presented in the form of odds ratios (ORs), with 95 per cent confidence intervals (CIs) and *p*-values. The fit of the logistic regression models was checked using Hosmer-Lemeshow and Pearson's goodness-of-fit tests. Collinearity between explanatory variables was assessed using the estimated variance inflation factors (VIFs).

The determinants of child stunting in Sri Lanka were further explored by undertaking a multilevel random intercept model to account for the hierarchical nature of the data set, which is discussed in Chapter 3, pp .58. A total of 7,259 children to 6,539 mothers in 6,459 households, nested within 2,304 communities were included in the sample. Based on the three-level structure, we had a choice to select either mother or the household as the second level within which children were nested. This study considered 3 level structure as: individual, household and community. There were two reasons to choose *household* rather than mother as the second level. First, a child's household situation (environmental influence) holds as important a key in predicting his or her nutritional status than do the genetic effects conferred by the mother (Mokgatlhe and Nnyepi, 2014). Second, the results of variance components models using both household and maternal levels revealed that the intra-class correlation (ICC) at the household level was slightly higher than it was for the mother at the second level for each child nutrition outcome.

5.4.4 Model building

The multivariate analysis consists of three logistic regression models. Model 1 included all the child (individual characteristics), Model 2 consisted of maternal biological and household characteristics, in addition to the child characteristics. Model 3 included all the child, maternal, household, residential and community characteristics.

Four models were fitted in the multilevel analysis. Model 0R is an empty model (null model) without explanatory variables, to test random variability in the intercept and to estimate the ICC. Model

IR examines the effects of individual-level characteristics, Model 2R adds maternal and household characteristics and Model 3R includes child, maternal, household and residential characteristics simultaneously. Factors that were included in the multivariate models were included in these models.

5.5 Results of the descriptive analysis

Table 5.2 shows the background characteristics of the children who were aged 6-59 months at the time of the survey. The mean age of the children was 33 months (2.9 years) (SD 15.4). Over half of children (51.5 per cent) were boys and 16.9 per cent were reported as low birth weight babies. About 75 per cent of children had no morbidity during the past two weeks of the survey. In terms of maternal characteristics, half of the respondents (50.1 per cent) were aged 21-29 years at the time of childbirth, and 49 per cent had a normal BMI level (18.5-24.9). The majority of the mothers were married (98.3 per cent), had passed Ordinary Level (66.6 per cent), and were unemployed (76.7 per cent). One-fourth of the mothers was in the lowest wealth quintile (25.3 per cent) and over half of the mothers (64.4 per cent) belonged to the Sinhalese ethnicity. Moreover, a substantial proportion of the households had improved sources of drinking water (91.1 per cent) and improved toilet facilities (97.7 per cent). The sample is predominantly rural (77.4 per cent), and 18.6 per cent of mothers are settled in the Western Province. Regarding the community-level characteristics, 48.9 per cent of the children were from poor communities and 41.2 per cent from a low maternal educational background.

The socioeconomic status of ethnic groups by sector is also considered. Sinhalese are economically better off compared to other ethnic groups, regardless of the sector they live in (Appendix E). However, Sinhalese in the rural and estate sector are economically disadvantaged than their counterparts in the urban sector. Tamils have the worst economic position compared to other ethnic groups.

Table 5.2 Background characteristics of the sample (N = 7,259)

Characteristics	Number	Percentage (per cent)
Age in months		
6-11	762	10.5
12-24	1,527	21.0
25-47	3,312	45.6
48-59	1,658	22.8
Sex		
Male	3,741	51.5
Female	3,518	48.6
Preceding birth Interval in months		
First birth	2,846	39.2
< 24	375	5.1
24-47	1,502	20.6
48 or more	2,536	34.9
Birth weight	n=7,029	
Normal weight	5,840	83.1
Low birth weight (<= 2500 grams)	1,189	16.9
Child morbidity status	n=7,251	
Not had diarrhoea/cough/fever	5,428	74.9
Had diarrhoea/cough/fever	1,823	25.1
Maternal characteristics		
Maternal age in years		
<= 20	278	3.8
21-29	3,639	50.1
30-34	2,127	29.3
35 or more	1,215	16.7
Maternal height	n=7,102	
Short <= 145 cm	502	7.0
Average 145.1-155 cm	3,946	55.5
Tall 155.1 cm and over	2,654	37.3
Maternal BMI	n=7,091	
BMI < 18.5	811	11.4
BMI 18.5-24.9	3,481	49.0
BMI 25.0-29.9	2,020	28.4
BMI >= 30.0	779	10.9

Characteristics	Number	Percentage (per cent)
Marital status	n=7,111	
Currently married/living together	6,991	98.3
Divorced/separated	98	1.4
Widowed	22	0.3
Mother's education		
Up to and including grade 5	365	5.0
Ordinary level	4,839	66.6
Advanced level	1,639	25.5
Degree and above	416	5.7
Maternal employment status		
Employed	1,687	23.2
Not employed	5,572	76.7
Household characteristics		
Wealth quintile		
Lowest	1,836	25.3
Second	1,493	20.7
Middle	1,344	18.4
Fourth	1,407	19.4
Highest	1,179	16.2
Household Size		
< 5 members	2,877	39.6
5-7 members	3,832	52.7
8 and more members	550	7.5
Ethnicity		
Sinhala	4,677	64.4
Indian Tamil	1,505	20.7
Sri Lanka Tamil	244	3.3
Muslims and other	833	11.4
Source of drinking water		
Improved	6,616	91.1
Not improved	643	8.8
Source of cooking fuel	n=4,873	
Traditional	4,871	67.2
Modern	2.369	32.7
Access to media		
Low	150	2.1

Characteristics	Number	Percentage (per cent)
Medium	3196	44.3
High	3865	53.6
Toilet facility	n=7,211	
Improved	7,094	97.7
Not improved	165	2.2
Owns livestock		
Yes	982	13.5
No	6,277	86.4
Residential sector		
Urban	1,159	15.9
Rural	5,624	77.4
Estate	476	6.5
Provinces		
Western	1,352	18.6
Central	920	12.6
Southern	859	11.8
Northern	887	12.2
Eastern	802	11
North-Western	784	10.8
North-Central	488	6.7
Uva	512	7.0
Sabaragamuwa	655	9.0
Community poverty	n=7,251	
Low	3,700	51.0
High	3,551	48.9
Community education		
Low	2,994	41.2
High	4,265	58.7

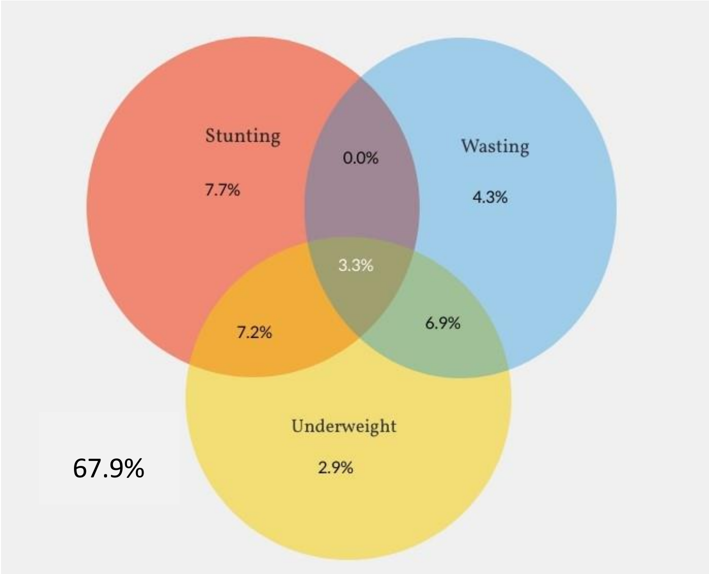
Table 5.3 shows the analysis of overall stunting, wasting and underweight rates of the children According to the findings, stunting, wasting and underweight were 18.2 per cent, 14.5 per cent and 20.7 per cent respectively, while 4.4 per cent of children were severely stunted, 2.7 per cent were severely wasted and 4.1 per cent were severely underweight. The mean of the HAZ was reported as -1.01 and the median was -1.02; for the WHZ, mean and median were reported as -0.85 and -0.91 respectively; for the WAZ the mean and median were -1.16 and -1.21 respectively. Histograms for each variable are presented in Appendix F.

Figure 5.1 shows the estimate for children who were stunted but were not underweight or wasted was 7.7 per cent, children who were underweight but not stunted and not wasted was nearly 3 per cent and children who were only wasted but not stunted or underweight is 4.3 per cent. There were no cases of children who were both stunted and wasted but who were not also underweight, also 67.9 per cent of children are reported as not stunted, wasted or underweight.

Table 5.3 Child anthropometric measures (*N* = 7,259)

Indicator	**Mean**	**Median**	**SD**	**Percentage**	**Number**
Height-for-age (HAZ) – Stunting					
Stunted (< -2 SD)	-1.01	-1.02	1.19	18.2	1,266
Severely stunted (< -3 SD)				4.4	310
Normal				81.8	5,691
Weight-for-height *z*-score (WHZ) – Wasting					
Wasted (< -2 SD)	-0.85	-0.91	1.18	14.5	1,008
Severely wasted (< -3 SD)				2.7	193
Normal				85.4	5,914
Weight-for-age *z*-score (WAZ) – Underweight					
Underweight (< -2 SD)	-1.16	-1.21	1.11	20.7	1,448
Severely underweight (< -3 SD)				4.1	287
Normal				79.2	5540

Figure 5.1 Venn diagram of child undernutrition outcomes



5.5.1 Initial data exploration of the sample

Children's underweight, stunting and wasting reflect different facets of undernutrition. They are also not mutually exclusive: for instance, a child who is found to be stunted can also be underweight and wasted at the same time.

The relationships between stunting (low height-for-age) and underweight (low weight-for-age), and between stunting and wasting (low weight-for-height) were explored through scatter plots as shown in Figure 5.2 and 5.3. Children with a higher weight-for-age *z*-score are more likely to have a higher height-for-age *z*-score, showing a moderate positive correlation coefficient of 0.65. In Figure 5.3, the correlation coefficient between height-for-age and weight-for-height was 0.07 revealing a weak relationship between stunting and wasting. This indicates variations in the children's body shape in terms of their height and weight for their age.

Figure 5.2 Plot of height-for-age and weight-for-age *z*-scores

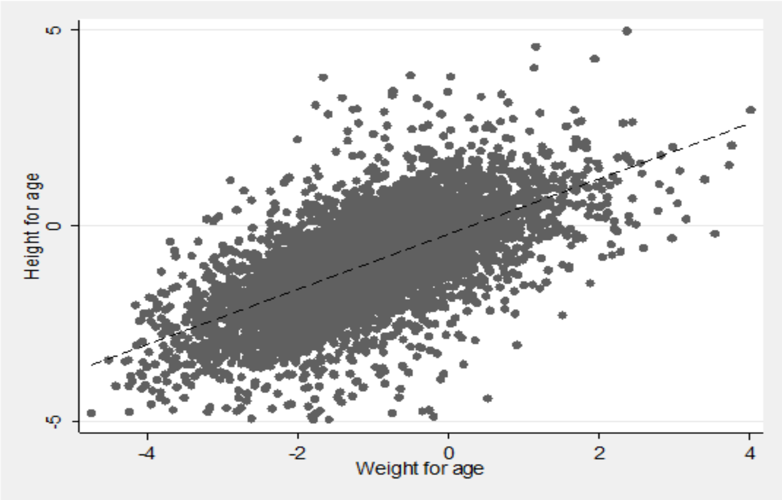


Figure 5.3 Plot of height-for-age and weight-for-height *z*-scores

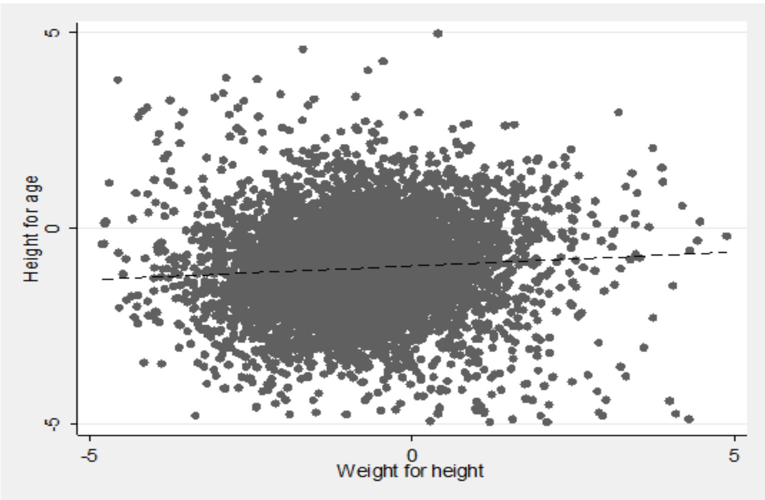


Figure 5.4 shows the proportion of children stunted by age and sex. The likelihood of stunting is higher amongst male children compared to female children aged between 6 months and 1 year, while female stunting rates are at the peak around 25-36 months. It is clearly visible that the proportion of children stunted markedly increases from birth to 24 months onwards and then the trend starts to decline as age increases further. A similar trend can be seen among underweight children by age and sex (Figure 5.5). From the age group 6 months to 36 months, the proportion of male children underweight is increasing gradually, however, after 36 months onwards, there is a decline. In contrast, for female children, the proportion of underweight is highest at the age 37-48 months, and then it declines.

Figure 5.4 Proportion of children stunted by age and sex

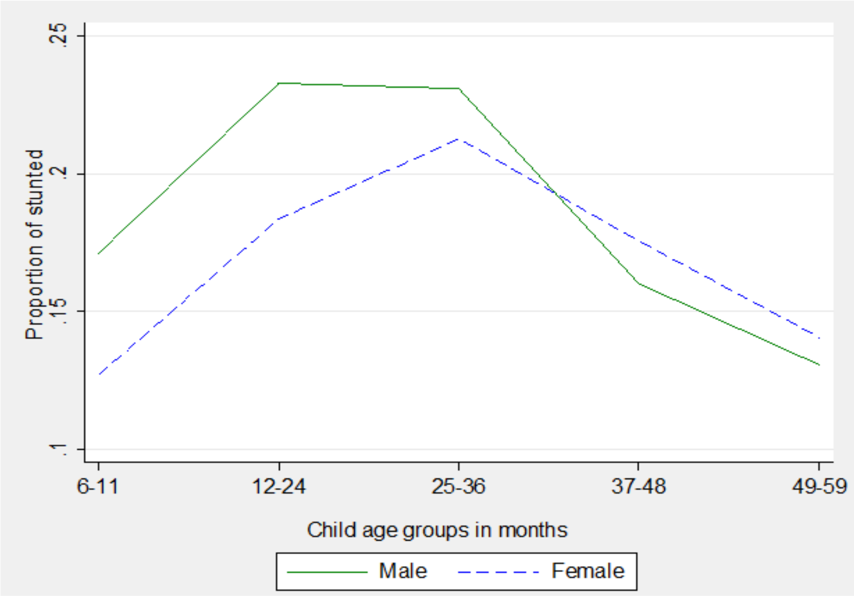
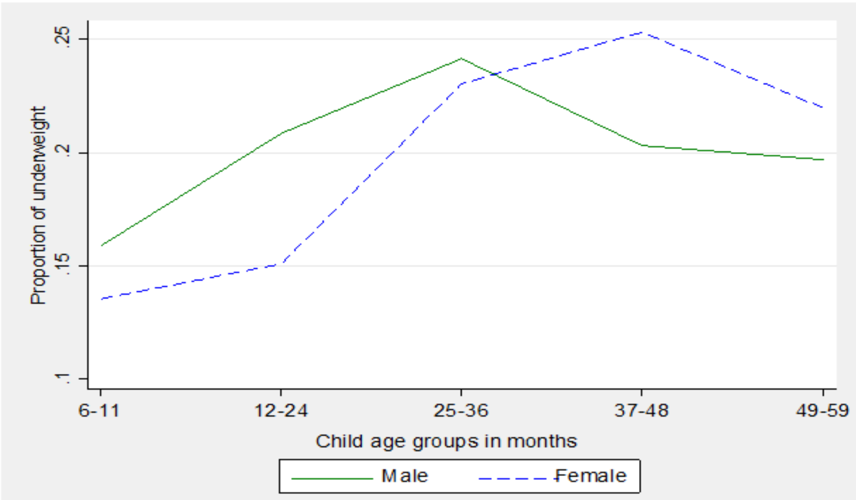


Figure 5.5 Proportion of children underweight by age and sex



Figures 5.6 and 5.7 show the differences in the proportion of children stunted and underweight between urban, rural and estate children by age group. The proportion of children who are stunted and underweight is consistently lower in the urban sector compared to both rural and estate sectors across all age groups. The estate sector shows the marked gap with the highest proportion of stunted and underweight children across every age group. The gap is highest at ages 25-36 months, while for underweight it is at the 37–48-month age group.

Figure 5.6 Proportion of children stunted by age and sector of residential sector

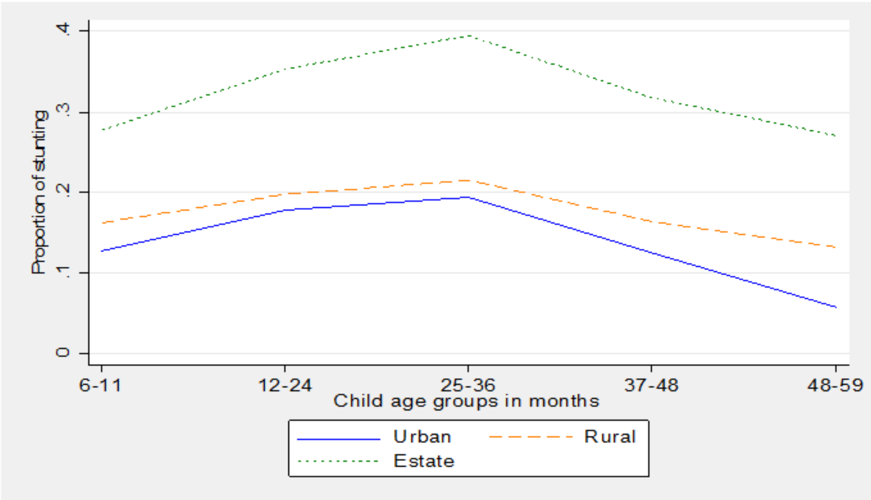


Figure 5.7 Proportion of children underweight by age and sector of residential sector

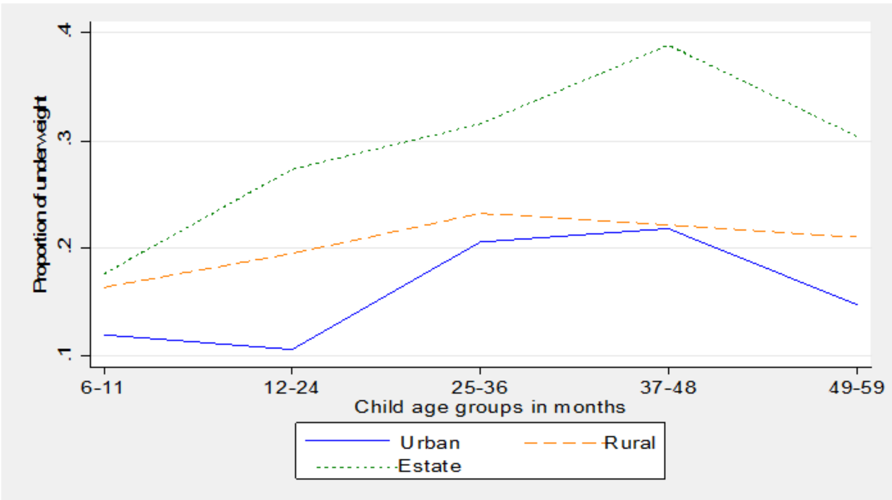
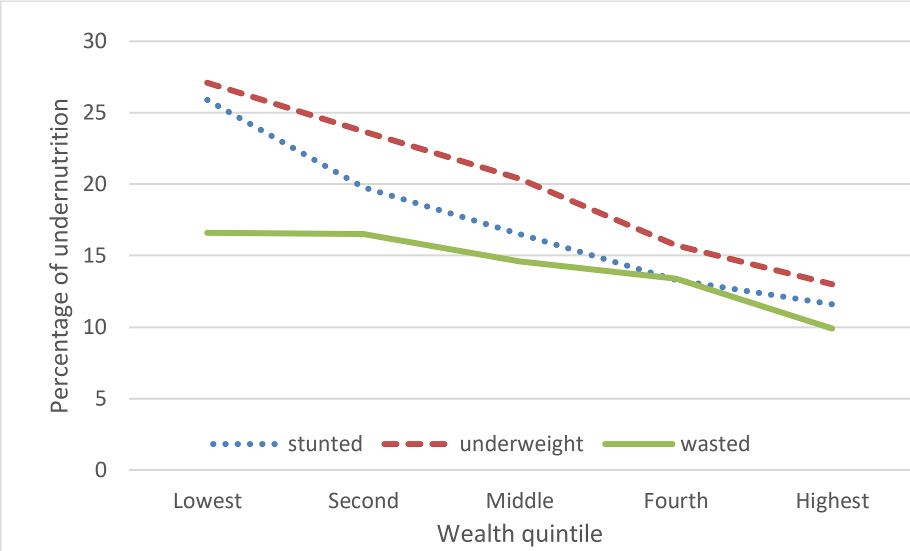


Figure 5.8 shows considerable disparities across the wealth groups that favour the well-off. For an instance, children in the lowest wealth quintile had the highest proportion stunted, wasted and underweight, followed by children in the second-lowest wealth quintile. A child belonging to the poorest wealth quintile is nearly two times more likely to be stunted and underweight than a child is in the richest quintile.

Figure 5.8 Stunting, underweight and wasting across wealth quintiles



Child stunting, wasting and underweight rates are illustrated by districts and these rates vary across most of the districts (Appendix G). For example, both child stunting and underweight rates are the highest in the Nuwara Eliya district (35 per cent and 32 per cent). Stunting rates are lowest in Polonnaruwa district followed by Puttalam district followed by (12 per cent), while the lowest underweight rate was reported in Jaffna district (14.7 per cent). Child wasting was least prevalent in districts including Badulla and Polonnaruwa (around 11 per cent), whereas the prevalence was highest in Monaragala district (24.9 per cent).

5.5.2 Socioeconomic inequalities in child nutrition

The calculation of the concentration index is discussed in Chapter 3, section 3.8, pp 64.

The negative signs of the concentration indices values confirm that the inequalities exist in child undernutrition. The greatest inequality is observed among child stunting, corresponding to a value of the concentration index of -0.158 at the national level, followed by underweight (−0.156). The results of the concentration index at the national level showed that the inequality in stunting, wasting and underweight was statistically significant and the children in lower quintiles suffered more from undernutrition.

This is also displayed in the concentration curves in Figure 5.9. Concentration curves for all anthropometric measures lie above the 45-degree line of equality, indicating that undernutrition levels have disproportionately affected children in poor households compared to those who were affluent.

The inequalities can be further disaggregated by the residential sector. As presented in Table 5.4, the estate sector has lower CIs (gap between poor and rich) compared to the other two sectors, however, the estate sector overall has higher undernutrition rates. The reason for this could be that most people in the estate sector are homogeneously poor and fall into the poorest wealth category, thus the estate sector is less likely to have large inequalities compared to the urban and rural sectors.

Figure 5.9 Concentration curves for child undernutrition

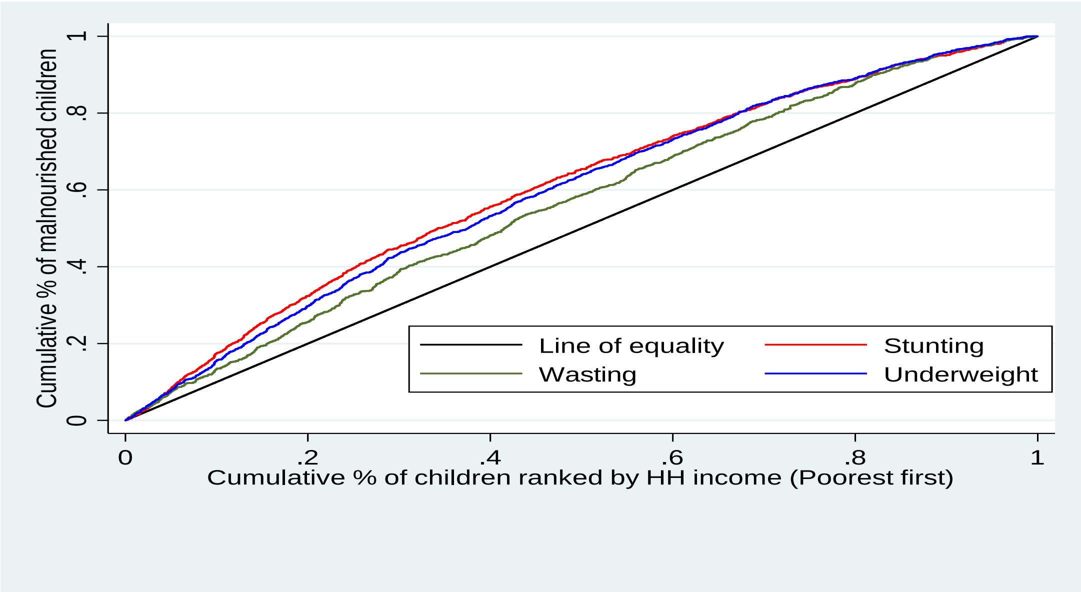


Table 5.4 Socioeconomic inequalities in child malnutrition by national and residential sectors

	Stunting		Wasting		Underweight	
Sector	**CI**	***p-value***	**CI**	***p-value***	**CI**	***p-value***
National	**-0.158**	**0.001**	**-0.095**	**0.000**	**-0.156**	**0.000**
Urban	-0.139	0.001	-0.105	0.024	-0.183	0.000
Rural	-0.147	0.000	-0.104	0.000	-0.145	0.000
Estate	-0.095	0.016	0.088	0.004	-0.007	0.869

p-values: Independent 2-tailed *t*-test to compare the values of the concentration indices equals 0.

5.5.3 Bivariate analysis of childhood stunting, wasting and underweight among under-five year old children by child, maternal, household and residential characteristics

Table 5.5 presents the associations between child stunting, wasting and underweight and background characteristics for children aged 6-59 months.

The relationship was explored using cross-tabulations and chi-square analysis. As expected, child's age, child's birth interval and birth weight were highly associated with both stunting and underweight. Children who were born with a low birth weight tend to have the highest stunting (33.6 per cent), wasting (23.1 per cent) and underweight (38.1 per cent) rates. Child morbidity status (child has had diarrhoea/cough/fever), was associated with stunting and wasting but not underweight. A child's sex was not significantly associated with any of the anthropometric outcomes.

Maternal biological factors such as BMI are significantly associated with all three outcomes, however, only maternal height was associated with stunting and underweight status. Maternal age had an association approaching conventional levels of statistical significance (p = 0.054) with the child being underweight: mothers who were aged under 20 have the highest percentage of underweight children. Maternal marital status, employment status and attended anc visits were not significantly associated with any of the outcomes, hence they are not reported in the table.

The socioeconomic variables wealth status, mother's education and maternal ethnicity were significantly associated with child nutritional outcomes. To take an example, most of the undernourished children's mothers had completed Ordinary Level education and Indian Tamil mothers had the highest rates of stunted (39.7 per cent) and underweight (30.7 per cent) children. Among the household factors, source of drinking water was significantly associated only with stunting and underweight rates, while source of cooking oil also shown a significant association with outcomes. Among other factors, access to media was associated only with a child's stunting and underweight status. The estate sector had the highest percentage of stunted (35 per cent) and underweight (31 per cent) when compared to other residential sectors. Thus, Central Province, where most of the estate sector population lives, had the highest rates of stunting (27.9 per cent) and underweight (23.8 per cent). Community characteristics, such as both community poverty and community maternal education were significantly associated with all child undernutrition outcomes.

Table 5.5 Distribution of children stunted, wasted and underweight by socioeconomic geographic factors (N=7,259)

Background Characteristics	Stunted (*N* = 6,957)			Wasted (*N* = 6,922)			Underweight (*N* = 6,988)		
	Per cent	***n***	***p*-value**	**Per cent**	***n***	***p*-value**	**Per cent**	***n***	***p*-value**
Total	18.2	1,266		14.5	1,008		20.7	1,448	
Age in months									
6-11	16.8	121	0.000	15.7	113	0.361	15.2	111	0.000
12-24	20.5	301		13.4	196		18.3	270	
25-47	19.8	632		14.3	455		23.2	741	
48-59	13.3	212		15.3	244		20.4	326	
Sex									
Male	18.7	673	0.184	15.0	535	0.281	20.9	752	0.703
Female	17.5	593		14.0	1,008		20.5	696	
Birth Interval in months									
First birth	15.8	430	0.000	13.0	354	0.008	19.1	525	0.022
< 24	21.2	76		15.8	56		20.7	74	
24-47	20.7	297		16.9	241		23.2	335	
48 or more	18.9	463		14.6	357		20.9	514	
Birth weight		*n* = 1,225			*n* = 980			*n* = 1,408	
Normal weight	14.9	838	0.000	12.7	714	0.000	17.1	967	0.000
LB weight	33.6	387		23.1	266		38.1	441	

Background Characteristics	Stunted (*N* = 6,957)			Wasted (*N* = 6,922)			Underweight (*N* = 6,988)		
	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value
Child morbidity status									
Not had diarrhoea/cough/fever	18.9	983	0.024	13.9	723	0.045	20.5	1,073	0.638
Had diarrhoea/cough/fever	16.0	273		16.3	279		21.1	362	
Maternal age (years)									
<= 20	19.2	52	0.647	16.9	45	0.166	24.4	66	0.054
21-29	18.4	639		15.0	521		21.7	757	
30-34	17.3	355		13.2	270		19.4	400	
35 or more	18.8	220		14.8	172		19.2	225	
Maternal height		*n* = 1,255			*n* = 994			*n* = 1,437	
Short <=145 cm	39.7	193	0.000	17.1	83	0.11	34.9	171	0.000
Average 145.1-155 cm	21.6	831		14.6	560		23.4	905	
Tall 155.1 & over	8.9	231		13.6	351		13.9	361	
Maternal BMI		*n* = 1,271			*n* = 998			*n* = 1,437	
BMI < 18.5	23.6	190	0.000	22.9	182	0.000	31.7	255	0.000
BMI 18.5-24.9	19.2	650		15.6	525		22.5	766	
BMI 25.0-29.9	16.1	321		11.8	233		16.4	325	
BMI >= 30.0	14.4	110		7.7	58		12.2	93	

Background Characteristics	**Stunted (*N* = 6,957)**			**Wasted (*N* = 6,922)**			**Underweight (*N* = 6,988)**		
	Per cent	***n***	***p*-value**	**Per cent**	***n***	***p*-value**	**Per cent**	***n***	***p*-value**
Mother's education									
Up to grade 5	30.8	109	0.000	17.7	62	0.000	17.7	62	0.000
Grade 6 to Ordinary Level	19.8	922		15.8	730		15.8	730	
Advanced Level	12.2	193		11.5	180		11.5	180	
Degree and above	10.6	42		9.1	36		9.1	36	
Household factors									
Wealth quintile									
Lowest	25.9	458	0.000	16.6	292	0.000	27.1	481	0.000
Second	19.8	285		16.5	235		23.7	341	
Middle	16.5	213		14.6	189		20.4	266	
Fourth	13.3	180		13.4	181		15.7	213	
Highest	11.6	130		9.9	111		13	147	
Household size									
<= 4 members	17.1	472	0.174	14.8	405	0.838	20.8	576	0.482
5-7 members	18.7	691		14.4	531		20.8	774	
8 and more members	19.6	103		13.8	72		18.6	98	
Ethnicity									
Sinhala	16.2	730	0.000	15.4	692	0.000	20.9	947	0.000
Sri Lankan Tamil	20.8	303		14.8	216		21	308	
Indian Tamil	39.7	87		12.6	27		30.7	67	

Background Characteristics	Stunted (*N* = 6,957)			Wasted (*N* = 6,922)			Underweight (*N* = 6,988)		
	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value
Sri Lankan Moor/Muslims	18.6	146		9.3	73		15.8	126	
Source of drinking water									
Improved	16.9	1077	0.000	14.5	922	0.868	19.9	1,270	0.000
Not improved	31.1	189		14.3	86		29.1	178	
Access to media									
Low	22.0	32	0.032	19.3	28	0.054	28.0	41	0.000
Medium	19.2	590		15.2	467		22.2	688	
High	17.0	629		13.5	498		18.9	700	
Toilet facility									
Improved	18.0	1227	0.045	14.5	982	0.495	20.5	1,406	0.081
Not improved	24.2	39		16.4	26		26.2	42	
Source of cooking fuel									
Traditional	20.2	950	0.000	15.4	722	0.001	23.2	1,093	0.000
Modern	13.8	313		12.6	283		15.4	350	
Owns livestock									
Yes	20.9	201	0.017	15.0	143	0.645	23.6	227	0.018
No	17.7	1,065		14.4	865		20.2	1,221	
Residential sector									
Urban	14.0	156	0.000	12.6	139	0.052	16.4	183	0.000
Rural	17.6	956		15.1	814		20.7	1,128	

Background Characteristics	Stunted (*N* = 6,957)			Wasted (*N* = 6,922)			Underweight (*N* = 6,988)		
	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value	Per cent	*n*	*p*-value
Estate	35.0	154		12.7	55		31.0	137	
Provinces									
Western	14.3	188	0.000	14.1	185	0.007	18.2	240	0.015
Central	27.9	244		11.7	102		23.8	209	
Southern	14.1	111		16.8	131		21.1	166	
Northern	17.6	152		16.1	138		18.3	158	
Eastern	18.8	149		11.5	91		19.2	153	
North-Western	15.8	121		14.5	110		21.6	165	
North-Central	16.1	77		16.2	77		22.2	106	
Uva	20.0	98		17.5	85		24	118	
Sabaragamuwa	20.5	126		14.5	89		21.3	133	
Community maternal education									
Low	22.2	641	0.000	16.6	476	0.000	25.5	739	0.000
High	15.3	625		13.1	532		17.3	709	
Community poverty									
Low	14.4	515	0.000	13.3	472	0.002	17.4	622	0.000
High	22.0	751		15.8	536		24.1	826	

5.6 Results of the multivariate analysis

5.6.1 Child stunting

Table 5.6 shows the results of multivariate logistic regression models, controlling for child, maternal, household and residential variables. In Model 1, child factors such as age of the children, low birth weight status and birth interval were found to be associated with the child stunting. The odds of stunting among children in the age group 12-47 months was higher (adjusted odds ratio (AOR) = 1.33, 95 per cent CI: [1.05-1.69]) than those in the age group 6-11 months. Moreover, LBW children were more likely to be stunted compared to normal birth weight children and the LBW children had higher odds of being stunted, after controlling for other child variables (AOR = 3.15, 95 per cent CI: [2.68-3.67]). Child morbidity status was not significant, even though it was marginally significant in the bivariate analysis and hence it was removed from the model.

Model 2 added maternal biological and household variables such as maternal BMI, mother's height, maternal education and maternal ethnicity and household wealth. While the child factors remained significant, maternal factors were independently associated with child stunting. Obese mothers (BMI 30 or more) had lower odds of having stunted children compared with those who had the lowest BMI (AOR = 0.74, 95 per cent CI: [0.57-0.96]). Similarly, compared to short mothers, those who were of medium and tall height had lower odds (AOR = 0.48, 95 per cent CI: [0.38-0.60]) and (AOR = 0.18, 95 per cent CI: [0.14-0.24]) of having stunted children.

Further, being an Indian Tamil woman was significantly associated with child stunting compared to other ethnicities (AOR = 1.79, 95 per cent CI: [1.26-2.55]). Also, Muslims and other ethnicities were shown higher odds of stunting. Household wealth was also controlled in the model, and children who were in the highest wealth group had a lower odds of stunting compared to those who were in the lowest wealth group. For example, children in the highest wealth group had 37 per cent less chance of being stunted compared to those in the lowest wealth group (AOR = 0.63, 95 per cent CI: [0.47-0.84]). Maternal education was also not significant in Model 2, once the wealth index was controlled, thus it was removed from Model 3. Interactions were tested in the models to consider for any potential confounding. It seems that children belonging to the Indian Tamil ethnicity and in the lowest wealth group were more likely to be stunted, however, interactions between wealth groups and ethnicity were tested in the final models and found to be insignificant.

Model 3 considered child, maternal, household and residential factors including residential sector, province, and community poverty and community education. However, after adjusting these variables, residential sector, community poverty and community education had no significant effect on childhood stunting ($p > 0.05$), and so they were removed from the model and results were not reported.

Children in Central Province had higher odds of being stunted compared to those in Western province. The Indian Tamil children born with low birth weight were more likely to be stunted. Many of these stunted children live in poor households in Central Province in Sri Lanka, which is predominantly based on the tea plantation.

Table 5.6 Multivariate logistic regression results of stunting for children aged 6-59 months (2016 Demographic and Health Survey) (N = 6,957)

	Model 1	**Model 2**	**Model 3**
Variables	**AOR (95% CI)**	**AOR (95% CI)**	**AOR (95% CI)**
Age in months			
6-11	1.00	1.00	1.00
12-47	1.33 (1.05,1.69) *	1.30 (1.01,1.61) *	1.28 (0.99,1.64) *
48-59	0.80 (0.61,1.06)	0.76 (0.57,1.02)	0.75 (0.56,1.05)
Birth weight			
Normal weight	1.00	1.00	1.00
LBW (<= 2500 grams)	3.15 (2.68,3.67) ***	2.58 (2.16,3.02) ***	2.58 (2.18,3.05) ***
Birth interval			
First birth	1 .00	1.00	1.00
< 24 months	1.40 (1.02,1.92) *	1.31 (0.93,1.85)	1.29 (0.92,1.81)
24-47 months	1.44 (1.20,1.74) ***	1.33 (1.10,1.62) **	1.32 (1.10,1.62) **
48 months or more	1.27 (1.08,1.50) **	1.16 (0.97,1.37)	1.18 (1.00,1.40) *
Maternal BMI			
BMI < 18.5		1.13 (0.91,1.41)	1.16 (0.93,1.45)
BMI 18.5-24.9		1.00	1.00
BMI 25.0-29.9		0.87 (0.73,1.03)	0.87 (0.73,1.04)
BMI >= 30.0		0.74 (0.57,0.96) *	0.75 (0.58,0.98) *
Maternal height			
Short <=145 cm		1.00	1.00

	Model 1	Model 2	Model 3
Variables	**AOR (95% CI)**	**AOR (95% CI)**	**AOR (95% CI)**
Average 145.1-155 cm		0.48 (0.38,0.60) ***	0.48 (0.38,0.60) ***
Tall 155.1 & over		0.18 (0.14,0.24) ***	0.19 (0.14,0.24) ***
Maternal education			
Up to grade 5		1.00	
Grade 6 to Ordinary Level		1.06 (0.78,1.44)	
Advanced Level		0.86 (0.60,1.22)	
Degree and above		0.89 (0.55,1.44)	
Ethnicity			
Sinhalese		1.00	1.00
Sri Lankan Tamil		1.18 (0.97,1.44)	1.15 (0.89,1.49)
Indian Tamils		1.79 (1.26,2.55) **	1.50 (1.05,2.16) *
Muslims and others		1.41 (1.12,1.76) **	1.34 (1.05,1.71) *
Wealth Index			
Lowest		1.00	1.00
Second		0.80 (0.65,0.99) *	0.79 (0.65,1.00)
Middle		0.70 (0.56,0.88) **	0.68 (0.55,0.88) *
Fourth		0.62 (0.48,0.78) **	0.60 (0.49,0.81) ***
Highest		0.63 (0.47,0.84) **	0.58 (0.47,0.85) ***
Province			
Western			1.00
Central			1.57 (1.21,2.00) ***
Southern			0.82 (0.61,1.08)
Northern			0.88 (0.61,1.26)
Eastern			1.11 (0.82,1.46)
North-Western			0.99 (0.75,1.31)
North-Central			0.97 (0.70,1.34)

	Model 1	Model 2	Model 3
Variables	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Uva			0.96 (0.71,1.32)
Sabaragamuwa			0.92 (0.68,1.23)

***P < 0.05 **P<0.01**P<0.001**

5.6.2 Child wasting

The multivariate logistic regression results for the child wasting are presented in Table 5.7, with the addition of child maternal, household, and residential factors.

Model 1 indicated that birth weight, birth interval and morbidity status (having diarrhoea, cough and fever last week) were significantly associated with child wasting. For example, the odds of childhood wasting increased by 25 per cent for children who had at least one of diarrhoea, cough, and fever during the last week (AOR = 1.25; 95 per cent CI: [1.06-1.47]), compared to those who had no recent illness. In addition, LBW children had higher odds of being wasted (AOR = 2.22; 95 per cent CI: [1.09-2.60]). The child's age and sex were not significant after controlling for other child factors; hence they were removed from the final model.

Model 2 added maternal and household factors in addition to the child factors. While the child factors remained significant, BMI and maternal education were significantly associated with child wasting. Thin mothers (BMI < 18.5) were much more likely to have had 'wasted' children than mothers with normal BMIs (AOR = 1.56, 95 per cent CI: [1.26-1.94]). In addition, mothers in the highest educational group had lower odds of wasted children compared to mothers who had only primary education (up to grade 5) (AOR = 0.49, 95 per cent CI: [0.29-0.83]). There was an association between child wasting and ethnicity. Compared to the majority Sinhala, all ethnic groups had lower odds of wasting but the effect was only significant for children of Muslim mothers (AOR = 0.63; 95 per cent CI: [0.47-0.83]). Maternal height was not significant, hence not included into the model. Household wealth did not show any significant association with wasting. Since wealth is used as the main measure of socioeconomic status, despite insignificant test statistics, wealth was placed in both models as wealth was hypothesised to be theoretically important in the model.

Model 3 added residential factors including residential sector, provinces, and community factors, but none of these factors showed any significant association with wasting. Furthermore, community poverty and community education were not significant and were removed from the final model. In conclusion, none of the household or community factors was significantly associated with child wasting status. Since the Indian Tamils ethnicity and wealth index were not significant in the models, interactions were not tested in the child wasting model.

Table 5.7 Multivariate logistic regression results for wasting for children aged 6-59 months (N = 6,922)

Variables	Model 1 **AOR (95%CI)**	Model 2 **AOR (95% CI)**	Model 3 **AOR (95%CI)**
Birth weight			
Normal weight	1.00	1.00	1.00
LBW (<=2500 grams)	2.22 (1.90,2.60) ***	2.06 (1.72,2.04) ***	2.11 (1.76,2.52) ***
Birth interval			
First birth	1.00	1.00	1.00
< 24 months	1.45 (1.01,2.01) *	1.64 (1.15,2.34) **	1.66 (1.17,2.37) **
24-47 months	1.52 (1.21,1.82) ***	1.63(1.33,1.99) ***	1.63 (1.33,1.43) ***
48 months or more	1.20 (1.01,1.40) *	1.20 (1.00,1.43) *	1.19 (1.00,1.43) *
Morbidity status (having diarrhoea, fever or cough last week)			
No	1.00	1.00	1.00
One of above	1.25 (1.06,1.47) **	1.23 (1.04,1.46) *	1.22 (1.03,1.45) *
Maternal BMI			
BMI < 18.5		1.56 (1.26,1.94) ***	1.60 (1.29,1.99) ***
BMI 18.5-24.9		1.00	1.00
BMI 25.0-29.9		0.73 (0.61,0.88) ***	0.73 (0.60,0.88) ***
BMI >= 30.0		0.49 (0.36,0.68) ***	0.48 (0.35,0.66) ***
Maternal education			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		0.94 (0.67-1.32)	0.94 (0.67-1.310
Advanced Level		0.75 (0.51-1.11)	0.69 (0.48-1.01)
Degree and above		0.49 (0.29-0.83) **	0.42 (0.25-3.28) **
Ethnicity			
Sinhalese		1.00	1.00
Sri Lankan Tamil		0.86 (0.69,1.08)	0.94 (0.69,1.28)
Indian Tamil		0.74 (0.46,1.21)	0.77 (0.46,1.28)
Muslims and others		0.63 (0.47,0.83) **	0.65 (0.48,0.88) **
Wealth Index		1.00	1.00
Lowest		1.20 (0.95,1.50)	1.19 (0.94,1.50)
Second		0.99 (0.78,1.27)	0.97 (0.76,1.26)
Middle		0.99 (0.76,1.28)	0.96 (0.74,1.26)
Fourth		0.81 (0.60,1.10)	0.78 (0.57,1.07)
Province			

Variables	Model 1 **AOR (95%CI)**	Model 2 **AOR (95% CI)**	Model 3 **AOR (95%CI)**
Western			1.00
Central			0.77 (0.58,1.040
Southern			1.05 (0.77,1.32)
Northern			1.00 (0.69,1.490
Eastern			0.82 (0.59,1.14)
North-Western			0.93 (0.71,1.23)
North-Central			1.17 (0.86,1.06)
Uva			1.20 (0.88,1.630
Sabaragamuwa			0.82 (0.60,1.11)

P < 0.05 **P<0.01P<0.001**

5.6.3 Child underweight

The multivariate logistic regression results for the underweight are given in Table 5.8. In Model 1, children who are aged 12-47 months, low birth weight children and those born with a preceding birth interval of 24-47 months were at an elevated risk of being underweight compared with other children. For example, a low birth weight child had 3.16 times the odds of being underweight compared to a normal birth weight child (AOR = 3.16, 95 per cent CI: [2.72-3.68]).

Model 2, with the addition of maternal and household factors, indicated that maternal height, BMI, maternal education, ethnicity and wealth were significantly associated with a child's low weight-for-age status. While child factors remained significant, the effect of LBW attenuated when adjusted for maternal and household factors. This model suggests an influence of maternal stature and economic status on child underweight status. In addition, having a mother with higher educational status (i.e degree and above) (AOR = 0.53, 95 per cent CI:[0.33-0.84]) and being a Sri Lankan Tamil or having Muslim ethnicity were associated with lower risk of being underweight (AOR = 0.80, 95 per cent CI: [0.66-0.97]) and AOR = 0.81, 95 per cent CI: [0.64–1.02]). With reference to household wealth, there was a clear negative relationship between increasing household wealth and the likelihood of underweight, with children from households in the fourth and richest quintiles experiencing decreased odds of underweight compared to those from the poorest households (AOR = 0.62, 95 per cent CI: [0.47-0.81]). Unlike the case of stunting, being of Indian Tamil ethnicity had no significant effect on child underweight ($p > 0.05$).

In Model 3, having controlled for child, maternal, household and residential factors, including sectors and provinces, most child, maternal and household wealth factors remained significant. However, ethnicity was no longer significant. Most of the factors such as child age, LBW, birth interval, height and BMI of the mother showed a consistent effect in Model 3, even after controlling for residential factors. Province showed a significant association with the chance of being underweight: children living in Sabaragamuwa Province had a reduced risk of being underweight (AOR = 0.75, 95 per cent CI: [0.57-1.00]).

Overall, residential sectors and community factors were not significant and were removed from the model. Interactions were tested for wealth groups by ethnicity; however, none was found insignificant and were thus not reported in the models.

Table 5.8 Multivariate logistic regression results of underweight for children aged 6-59 months (*N* = 6,988)

Variables	**Model 1**	**Model 2**	**Model 3**
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Age in months			
6-11 months	1.00	1.00	1.00
12-47 months	1.53 (1.20,1.94) ***	1.52 (1.18,1.95) **	1.52 (1.18,1.95) **
48-59 months	1.39 (1.07,1.81) *	1.39 (1.05,1.83) *	1.39 (1.05,1.83) *
Birth weight			
Normal weight	1.00	1.00	1.00
LBW(<= 2500 grams)	3.16 (2.72,3.68) ***	2.60 (2.21,3.05) ***	2.60 (2.21,3.05) **
Birth interval			
First birth	1.00	1.00	1.00
< 24 months	1.21 (0.89,1.66)	1.28 (0.92,1.77)	1.28 (0.92,1.77)
24-47 months	1.30 (1.09,1.55) **	1.29 (1.08,1.55) **	1.29 (1.08,1.55) **
48 months or more	1.12 (0.96,1.30)	1.04 (0.89,1.22)	1.04 (0.89,1.22)
Maternal BMI			
BMI < 18.5		1.45 (1.20,1.78) ***	1.48 (1.21,1.80) ***
BMI 18.5-24.9		1.00	1.00
BMI 25.0-29.9		0.72 (0.61,0.85) ***	0.72 (0.52,1.03) ***
BMI >= 30.0		0.54 (0.41,0.70) ***	0.54 (0.41,0.70) ***
Maternal height			
Short <=145 cm		1.00	1.00
Average 145.1-155 cm		0.65 (0.51,0.82) ***	0.65 (0.51,0.82) ***
Tall 155.1 & over		0.39 (0.30,0.50) ***	0.38 (0.30,0.50) ***
Maternal education			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		0.90 (0.67,1.20)	0.91 (0.68,1.12)
Advanced Level		0.72 (0.51,1.00) *	0.73 (0.52,1.03)
Degree and above		0.53 (0.33,0.84) **	0.53 (0.33,0.86) *
Ethnicity			

Variables	**Model 1**	**Model 2**	**Model 3**
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Sinhalese		1.00	1.00
Sri Lankan Tamil		0.80 (0.66,0.97) *	0.87 (0.68,1.12)
Indian Tamils		1.07 (0.73,1.58)	1.04 (0.69,1.56)
Muslims and others		0.81 (0.64,1.02) *	0.79 (0.62,1.02)
Wealth Index			
Lowest		1.00	1.00
Second		0.97 (0.80,1.18)	0.95 (0.78,1.17)
Middle		0.81 (0.66,1.00)	0.79 (0.64,0.98) *
Fourth		0.62 (0.50,0.79) ***	0.61 (0.48,0.77) ***
Highest		0.62 (0.47,0.81) ***	0.60 (0.46,0.80) ***
Province			
Western			1.00
Central			1.05(0.82,1.34)
Southern			0.94 (0.73,1.20)
Northern			0.76 (0.53,1.08)
Eastern			0.96 (0.73,1.27)
North-Western			1.02 (0.79,1.31)
North-Central			1.13 (0.84,1.52)
Uva			1.02 (0.77,1.36)
Sabaragamuwa			0.75 (0.57,1.00) *

P < 0.05 **P<0.01**P<0.001

5.7 Results of the multilevel analysis

5.7.1 Child stunting

Results of the multilevel logistic regression model are presented in Table 5.9. The null model (Model 0R) had a three-level random intercept, which showed statistically significant variability in the odds of a child being stunted between households within the community (τ = 1.84, *p* = 0.000). This was further proved by the intra-class correlation (ICC) in the empty model: about 7 per cent (0.067) of the unexplained variance of stunting for children was due to variation between communities. This value suggests the correlations between clusters are not strong. By contrast, 40 per cent of variation (ICC=0.40) in stunting was attributed to differences between households within the community.

In Model 1R, all the child factors including child age, low birth weight status, birth interval were significantly associated with child stunting. In terms of child factors, LBW has a strong influence on child stunting, LBW children showing 4.18 times the odds of being stunted compared with children of normal birth weight (AOR = 4.18; 95 per cent CI: [3.24-5.40]). The intra-class correlation (ICC) was significantly reduced for both community and household levels compared to the null model after individual covariates were added to the model. The ICC shows that 5 per cent of the unexplained variance in child stunting was attributable at the community level, while it was 38 per cent for the households within communities.

In Model 2R, maternal biological and household factors were added. While child characteristics remained significant, BMI, height, wealth and ethnicity were significantly associated with child stunting. Unlike the fixed model of stunting, maternal education status was significant when compared to children of mothers who had completed primary education (up to grade 5), children of mothers who had completed their Advanced Level had a lower risk of being stunted (AOR = 0.67; 95 per cent CI: [0.45-1.01]).

Model 3R added covariates at the residential and community level. The random part of the model shows that household-level variance was further reduced to 1.24 from 1.40, reducing the community level ICC to 0.020 and the residual community-level variance to 0.09. Maternal education was not significant in this model; however, Central Province had a higher risk of child stunting after other factors had been taken into consideration (AOR = 1.70; 95 per cent CI: [1.26-2.32]). The ICCs for households nested within communities and between communities were also reduced to 0.28 and 0.02 respectively.

The multilevel models of child stunting demonstrate the variation that exists between households in the community, making it crucial to analyse child stunting prevalence at the household within communities. The model fit statistics, such as AIC (Akaike information criterion) and BIC (Bayesian information criterion) values indicate that Model 3R has the smallest values of model selection criteria such as the likelihood, AIC and BIC. This demonstrates that model controlling for individual, maternal biological, household and residential variables best accounts for variation in childhood stunting between households within communities.

.

Table 5.9 Multilevel logistic regression results of stunting for children aged 6-59 months (2016 Demographic and Health Survey) (*N* = 6,957)

Variables	**Model OR** **AOR (95% CI)**	**Model 1R** **AOR (95% CI)**	**Model 2R** **AOR (95%CI)**	**Model 3R** **AOR (95%CI)**
Age in months				
6-11 months		1.00	1.00	1.00
12-47 months		1.30 (0.99,1.71)	1.26 (0.96,1.65)	1.23 (0.94,1.60)
48-59 months		0.67 (0.48,0.91) *	0.65 (0.47,0.89) *	0.64 (0.46-0.87) **
Birth weight				
Normal weight		1.00	1.00	1.00
LBW(<= 2500 grams)		4.18 (3.24,5.40) ***	3.44 (2.38,3.78) ***	3.00 (2.38,0.87) ***
Birth interval				
First birth		1.00	1.00	1.00
< 24 months		1.66 (1.14,2.04) **	1.51 (1.04,2.18) *	1.48 (1.03,2.14)
24-47 months		1.69 (1.36,2.13) ***	1.50 (1.20,1.87) ***	1.49 (1.19,1.86) ***
48 months or more		1.38 (1.14,1.68) **	1.22 (1.01,1.48) *	1.23 (1.01,1.49)

Variables	Model OR AOR (95% CI)	Model 1R AOR (95% CI)	Model 2R AOR (95%CI)	Model 3R AOR (95%CI)
Maternal BMI				
BMI < 18.5			1.18 (0.92,1.54)	1.20 (0.94,1.56)
BMI 18.5-24.9			1.00	1.00
BMI 25.0-29.9			0.80 (0.66,0.98) *	0.81 (0.67,0.99) *
BMI >= 30.0			0.71 (0.53,0.96) *	0.72 (0.54,0.96) *
Maternal height				
Short <=145 cm			1.00	1.00
Average 145.1-155 cm			0.36 (0.26,0.47) ***	0.37 (0.28,0.50) ***
Tall 155.1 & over			0.12 (0.08,0.17) ***	0.12 (0.08,0.18) ***
Maternal education				
Up to grade 5			1.00	1.00
Grade 6 to Ordinary Level			0.93 (0.66,1.32)	0.96 (0.68,1.37)
Advanced Level			0.67 (0.45,1.01) *	0.69 (0.46,1.03)
Degree and above			0.65 (0.37,1.12)	0.68 (0.39,1.17)
Ethnicity				
Sinhalese			1.00	1.00

Variables	Model OR AOR (95% CI)	Model 1R AOR (95% CI)	Model 2R AOR (95%CI)	Model 3R AOR (95%CI)
Sri Lankan Tamil			1.19 (0.95,1.50)	1.23 (0.91,1.65)
Indian Tamils			2.22 (1.43,3.45) ***	1.72 (1.10,2.69) *
Muslims and others			1.40 (1.07,1.83) *	1.33 (1.00,1.77)
Wealth Index				
Lowest			1.00	1.00
Second			0.78 (0.61,0.99) *	0.78 (0.61,0.99)
Middle			0.67 (0.51,0.88) **	0.66 (0.51,0.87) **
Fourth			0.55 (0.42,0.74) ***	0.56 (0.42,0.75) ***
Highest			0.59 (0.43,0.83) **	0.59 (0.42,0.83) **
Province				
Western				1.00
Central				1.70 (1.26,2.32) **
Southern				0.79 (0.57,1.11)
Northern				0.83 (0.56,1.24)
Eastern				1.06 (0.75,1.52)
North-Western				1.00 (0.72,1.38)

Variables	Model OR AOR (95% CI)	Model 1R AOR (95% CI)	Model 2R AOR (95%CI)	Model 3R AOR (95%CI)
North-Central				0.98 (0.67,1.43)
Uva				1.01 (0.69,1.46)
Sabaragamuwa				0.95 (0.68,1.35)
Covariance Estimates				
Random effect				
Community level variance (SE)	0.37 (0.13)	0.26 (0.12)	0.14 (0.17)	0.09 (0.10)
Household variance (SE)	1.84 (0.55)	1.72 (0.54)	1.40 (0.62)	1.24 (0.47)
Intra -class correlation				
ρ Community	0.067	0.052	0.026	0.020
ρ (Household, community)	0.401	0.382	0.305	0.280
Model fit statistics				
Log–likelihood	-3276.6	-3048.8	-2837.49	-2823.60
AIC*	6559.3	6115.7	5722.9	5711.2
BIC*	6579.9	6177.1	5886.4	5829.5

P < 0.05 **P<0.01P<0.001**

AIC:Akaike information criterion

BIC:Bayesian information criterion

5.7.2 Child wasting

Table 5.10 describes the results of the random-effects models at both community and household level for child wasting. Results show a small, estimated variance (0.31) between children in the same community, and a stronger, but modest, variance between households within communities (1.80).

This is further examined through the estimated intra-class correlation results. The correlation between children in the community was 0.05 (positive but small). There was a stronger, but still modest, correlation of 40 per cent between households within the community (ICC = 0.39).

The effect of most of the covariates was decreased compared to the fixed effects model of wasting, though the impact of low birth weight was increased. Model 3R controls for a child, maternal, household wealth and provinces covariates, and in this model, the estimated intra-class correlation between children in different households was 28 per cent, even though the household wealth and provinces do not have any effect on child wasting. The main source of variation for wasting was attributable to child and maternal biological factors.

The model fit statistics, such as the AIC and BIC values of Model 0R, Model 1R, Model 2R and Model 3R suggest that the Model 3R has the best fit in explaining the variation in child wasting between households within communities.

Table 5.10 Multilevel logistic regression results of wasting for children aged 6-59 months (N = 6,922)

Variables	**Model 0R**	**Model 1R**	**Model 2R**	**Model 3R**
	AOR (95%CI)	**AOR (95%CI)**	**AOR (95%CI)**	**AOR (95%CI)**
Birth weight				
Normal weight		1.00	1.00	1.00
LBW (<= 2500 grams)		2.48 (1.98,3.10) ***	2.16 (1.74,2.69) ***	2.19 (1.76,2.72) ***
Birth interval				
First birth		1.00	1.00	1.00
< 24 months		1.45 (0.98,2.13) *	1.65 (1.12,2.43) *	1.65 (1.12,2.41) **
24-47 months		1.56 (1.24,1.97) ***	1.65 (1.31,2.08) ***	1.63 (1.30,2.05) ***
48 months or more		1.23 (1.01,1.50) *	1.23 (1.01,1.50) *	1.22 (1.00,1.48) *
Child morbidity status				
No		1.00	1.00	1.00
One of above		1.30 (1.07,1.57) *	1.26 (1.04,1.53) *	1.25 (1.04,1.51) *
Maternal BMI				
BMI < 18.5			1.67 (1.29,2.14) ***	1.57 (1.27,1.96) ***
BMI 18.5-24.9			1.00	1.00
BMI 25.0-29.9			0.70 (0.57,0.87) ***	0.71 (0.61,0.88) ***
BMI >= 30.0			0.44 (0.31,0.62) ***	0.46 (0.36,0.67) ***

Variables	Model 0R	Model 1R	Model 2R	Model 3R
	AOR (95%CI)	AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
Maternal education				
Up to grade 5			1.00	1.00
Grade 6 to Ordinary Level			0.91 (0.62,1.32)	0.85 (0.59,1.24)
Advanced Level			0.70 (0.45,1.08)	0.67 (0.43,1.03)
Degree and above			0.50 (0.27,0.91) *	0.47 (0.26,0.85) *
Ethnicity				
Sinhalese			1.00	1.00
Sri Lankan Tamil			0.85 (0.67,1.08)	0.80 (0.58,1.11)
Indian Tamils			0.49 (0.28,0.86) *	0.54 (0.31,0.93) *
Muslims and others			0.54 (0.39,0.75) ***	0.57 (0.41,0.80) **
Household factors				
Wealth index				
Lowest			1.00	1.00
Second			1.11 (0.86,1.43)	1.12 (0.87,1.44)
Middle			0.95 (0.72,1.26)	0.97 (0.74,1.28)
Fourth			0.93 (0.70,1.23)	0.93 (0.70,1.24)
Highest			0.77 (0.54,1.08)	0.78 (0.55,1.10)

Variables	Model 0R	Model 1R	Model 2R	Model 3R
	AOR (95%CI)	**AOR (95%CI)**	**AOR (95%CI)**	**AOR (95%CI)**
Province				
Western				1.00
Central				0.73 (0.52,1.01)
Southern				1.00 (0.73,1.37)
Northern				1.21(0.80,1.84)
Eastern				0.80 (0.55,1.16)
North-Western				0.92 (0.66,1.27)
North-Central				1.15 (0.79,1.66)
Uva				1.18 (0.82,1.70)
Sabaragamuwa				0.72 (0.50,1.04)
Covariance estimates				
Random effect				
Community variance (SE)	0.31 (0.03)	0.28 (0.14)	0.16 (0.13)	0.12 (0.12)
Household variance (SE)	1.80 (0.59)	1.54 (0.57)	1.29 (0.53)	1.15 (0.50)
Intra -class correlation				
ρ (Community)	0.056	0.054	0.033	0.028
ρ (Household, community)	0.390	0.350	0.340	0.280

Variables	Model 0R	Model 1R	Model 2R	Model 3R
	AOR (95%CI)	AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
Model fit statistics				
Log-likelihood	-2854.7	-2730.82	-2639.9	-2631.62
AIC	5715.5	5479.6	5329.9	5327.24
BIC	5736	5540.9	5491.3	5445.02

P < 0.05 **P<0.01**P<0.001

AIC: Akaike information criterion

BIC: Bayesian information criterion

5.7.3 Child underweight

The results of the multilevel models for underweight are presented in Table 5.11. Model 0R demonstrates a variance of 0.23 at the community level, however, there is a variance of 1.64 between households within communities. The results of the ICC for statistics of the null model show that the community and household level ICCs are 0.04 and 0.36, respectively. This indicates that differences between households within a community explain more variability in the prevalence of underweight among children than the differences between communities.

The effect of the covariates is similar to that in the comparable fixed effects model, except in a few cases which showed an increased effect. For example, Model 1R which includes child covariates shows that children's underweight was significantly influenced by the low birth weight status (AOR = 4.01, 95 per cent CI: [3.19–5.02]) and other factors such as child's age and birth interval.

Compared to the null model, in Model 1R the estimated-community level variance was slightly reduced to 0.14 and the between household variance was also reduced to 1.43; as a response, the estimated ICC for underweight for children in the same communities was only 2 per cent while that among children in the household was 32 per cent. The effects of the covariates were similar to the fixed effects model, however, some of the effects were increased including age and birth weight. In Model 2R; for example, comparing the children in poor households, children in the richest households had 40 per cent lower odds of being underweight than children in the poorest households (AOR = 0.60, 95 per cent CI: [0.45-0.81]). Maternal education was significant; however, the effect was reduced compared to the fixed-effect model.

The estimated variance and intra-class correlation were further reduced in the final model (Model 3R) which was built by adding province to the existing covariates. Children in the Sabaragamuwa Province were less likely to be underweight (AOR = 0.71; 95 per cent CI: [0.52-0.96]) once all covariates were included. Model fit statistics such as low values of log-likelihood, AIC and BIC imply that Model 2R with the addition of the maternal biological and household variables but without province was the best model.

Table 5.11 Multilevel logistic regression results of underweight for children aged 6-59 months (N = 6,988)

Variables	**Model OR**	**Model 1R**	**Model 2R**	**Model 3R**
	AOR (95% CI)	**AOR (95% CI)**	**AOR (95% CI)**	**AOR (95% CI)**
Age in groups				
6-11 months		1.00	1.00	1.00
12-47 months		1.67 (1.28,2.18) ***	1.66 (1.28,2.16) ***	1.65 (1.27,2.15) ***
48-59 months		1.53 (1.14,2.06) **	1.53 (1.15,2.04) **	1.54 (1.15,2.05) **
Birth weight				
Normal weight		1.00	1.00	1.00
LBW (<= 2500 grams)		4.01 (3.19,5.02) ***	2.96 (2.41,3.63) ***	2.97 (2.42,3.65) ***
Birth interval				
First birth		1.00	1.00	1.00
< 24 months		1.12 (0.79,1.59)	1.16 (0.82,1.64)	1.17 (0.83,1.65)
24-47 months		1.49 (1.21,1.83) ***	1.44 (1.18,1.76) ***	1.44 (1.18,1.76) ***
48 months or more		1.21 (1.02,1.44) *	1.11 (0.94,1.32)	1.11 (0.93,1.32)
Maternal height				
Short <=145 cm			1.00	1.00
Average 145.1-155 cm			0.56 (0.43,0.73) ***	0.56 (0.43,0.74) ***
Tall 155.1 & over			0.30 (0.22,0.41) ***	0.30 (0.22,0.41) ***
Maternal BMI				
BMI < 18.5			1.55 (1.24,1.93) ***	1.55 (1.24,1.94) ***
BMI 18.5-24.9			1.00	1.00

Variables	Model OR	Model 1R	Model 2R	Model 3R
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
BMI 25.0-29.9			0.66 (0.55,0.80) ***	0.67 (0.55,0.80) ***
BMI >= 30.0			0.49 (0.37,0.66) ***	0.49 (0.37,0.66) ***
Maternal education				
Up to grade 5			1.00	1.00
Grade 6 to Ordinary Level			0.75 (0.55,1.03)	0.77 (0.56,1.06))
Advanced Level			0.57 (0.39,0.82) *	0.59 (0.41,0.86) **
Degree and above			0.42 (0.25,0.70)	0.43 (0.26,0.73) *
Ethnicity				
Sinhalese			1.00	1.00
Sri Lankan Tamil			0.79 (0.64,0.97) *	0.90 (0.68,1.19)
Indian Tamils			0.92 (0.61,1.39)	0.90 (0.59,1.38)
Muslims and others			0.74 (0.57,0.96) *	0.75 (0.57,0.98)
Wealth index				
Lowest			1.00	1.00
Second			0.91 (0.73,1.13)	0.89 (0.71,1.10)
Middle			0.78 (0.61,0.98) *	0.75 (0.59,0.96) *
Fourth			0.59 (0.45,0.76) ***	0.56 (0.43,0.73) ***
Highest			0.60 (0.45,0.81) **	0.58 (0.42,0.79) **
Province				
Western				1.00

Variables	Model OR	Model 1R	Model 2R	Model 3R
	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)	AOR (95% CI)
Central				1.00 (0.76,1.32)
Southern				0.96 (0.73,1.27)
Northern				0.76 (0.52,1.09)
Eastern				0.92 (0.67,1.27)
North-Western				1.03 (0.77,1.36)
North-Central				1.18 (0.85,1.63)
Uva				1.04 (0.76,1.44)
Sabaragamuwa				0.71 (0.52,0.96) *
Covariance Estimates				
Random Effect				
Community variance (SE)	0.23 (0.11)	0.14 (0.11)	0.07 (0.10)	0.00 (0.00)
Household variance (SE)	1.64 (0.50)	1.43 (0.47)	1.02 (0.41)	1.00 (0.20)
Intra-class correlation				
ρ (Community)	0.044	0.027	0.015	0.000
ρ (Community, household)	0.362	0.325	0.230	0.234
Model fit statistics				
Log-likelihood	-3546.83	-3323.07	-3157.04	-3151.4
AIC	7099.6	6664.14	6362.086	6366.81
BIC	7120.2	6725.55	6525.64	6584.89

P < 0.05 **P<0.01**P<0.001

AIC: Akaike information criterion   BIC: Bayesian information criterion

5.7.4 Effects of specific household factors on child stunting and underweight

The wealth index is a composite measure of the cumulative living standard of a household. This is constructed using a wide range of variables including ownership of durable or other assets, housing characteristics, sanitary facilities and access to such services as electricity and drinking water that are related to the wealth status of the household (Pirani, 2014). To assess the relationship between specific household variables used to construct the wealth index and child nutrition indicators, a separate model was constructed using these specific variables in place of the wealth index. The analysis was done for child stunting and underweight models, as the wealth index was not significant in the model of child wasting. The selected household variables were chosen based on the literature, discussed as significant determinants of stunting, wasting and underweight in Sri Lanka. This new model controlled for child, maternal and residential factors. There were no large disparities of odds ratios for other children, maternal and residential covariates compared with previous tables, hence only the effects of the specific factors of the wealth index are reported in Appendix H.

According to the results, children who did not have access to improved water were 28 per cent more likely to be stunted (AOR = 1.28; 95 per cent CI: [1.00, 1.63]) compared to children who had access to improved water sources after adjusting for all other variables. Overall, the results show that these specific household factors only have a limited effect on the chance of a child being stunted.

For underweight, availability of livestock and using traditional cooking fuel are associated with an increased risk of a child being underweight. For example, lack of availability of livestock at the household has lower odds (AOR = 0.79; 95 per cent CI: [0.64,0.98]), and cooking using unimproved fuel, including kerosene, wood, etc. is associated with increased odds for underweight compared to other children (AOR = 1.19; 95 per cent CI: [1.00,1.40]).

5.8 Effects of infant and young child feeding (IYCF) practices on child nutrition for children aged 6-23 months

The prevalence of IYCF practices was explored using a frequency table (Table 5.12). These indicators were recorded according to the information about the food given to the child in the last 24 hours before the interview. Among the 2,286 children who were aged 6–23 months, 92.6 per cent were still being breastfed, and 69.7 per cent achieved minimum dietary diversity (at least four food groups). The percentage of children who achieved the minimum required meal frequency was 82.8 per cent, and 82.2 per cent of children were fed iron-rich foods in the preceding 24 hours.

Table 5.12 Prevalence of IYCF practices among children age 6–23 months (*n*=2,286)

IYCF practices	**Frequency (n)**	**Percentage (%)**
Currently breastfed		
Yes	2,113	92.6
No	167	7.3
Minimum meal frequency		
Yes	1,750	82.8
No	363	17.1
Minimum dietary diversity		
Yes	1,595	69.7
No	691	30.2
Consumption of iron rich foods		
Yes	1,879	82.2
No	407	18.8

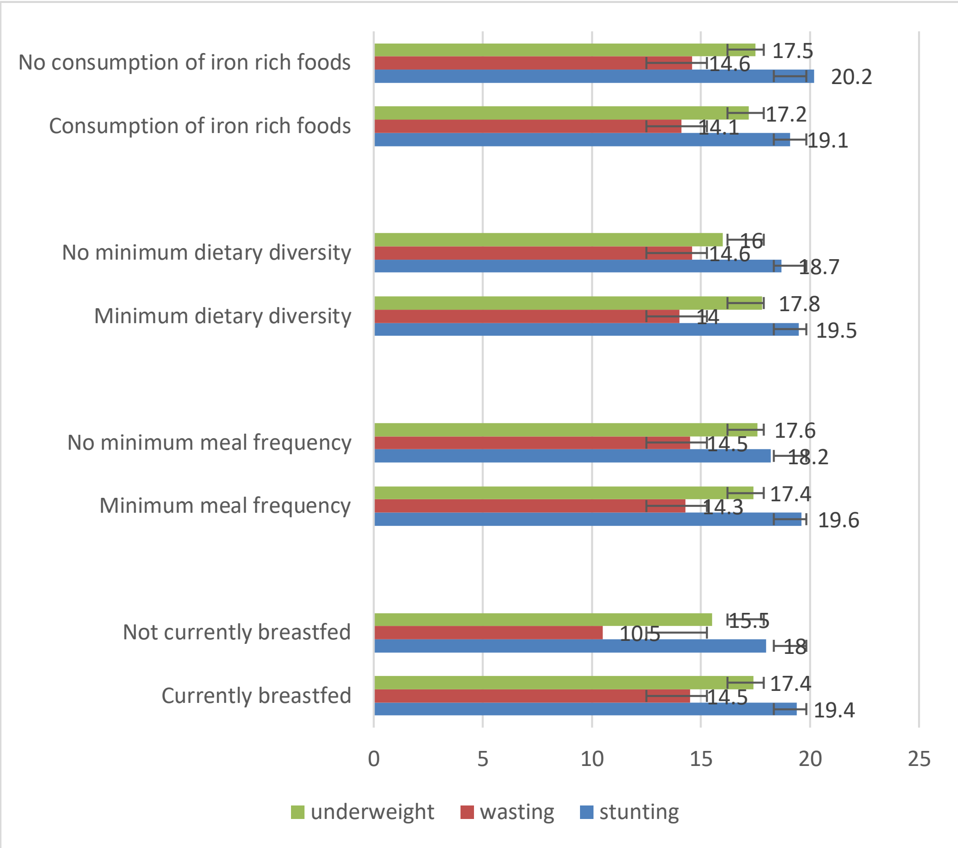
Table 5.13 presents the patterns of consuming foods by 6-11 months, 12-23 and 6-23 months. It is observed an increase in the consumption of all food groups among children aged 12-23 months compared to 6-11 months. The consumption of grains, roots and tubers shows the highest proportion (91.7 per cent for 6-23 months) followed by Vitamin A-rich fruits and vegetables (80.9 per cent for children aged 6-23 months) in both age groups. However, eggs were the least consumed food (30.0 per cent) followed by the other fruits and vegetables (43.4 per cent) during the 24-hour recall period.

Table 5.13 Percentages of children consuming food in different food groups by age groups 6-11 (n=760), 12-23(n=1,526) and 6-23 (n=2,286) months

Food group	**Age of child (in months)**					
	6-11		**12-23**		**6-23**	
	n	(%)	**n**	(%)	**n**	(%)
Grains, roots and tubers	625	82.2	1,472	96.4	2,097	91.7
Legumes and nuts	420	55.2	994	65.1	1,414	61.8
Dairy products (milk, yogurt, cheese)	357	46.9	949	62.1	1,306	57.1
Flesh foods (meat, fish, poultry and liver/organ meats)	367	48.4	1,002	65.7	1,462	64.0
Eggs	159	20.9	517	34.5	686	30.0
Vitamin A-rich fruits and vegetables	548	72.1	1,302	85.3	1,805	80.9
Other fruits and vegetables	236	31.0	757	49.6	993	43.4

Figure 5.10 shows the association of the prevalence of stunting, wasting and underweight percentages among children aged 6-23 months by IYCF practice. Child undernutrition was more prevalent in children who were currently breastfed compared with those who were not currently breastfed. Children who were received minimum meal frequency (14.3 per cent) and dietary diversity (14 per cent) and consumed iron-rich foods (14.1) had low wasting rates compared to other children. Moreover, consumption of iron-rich food had a lower prevalence of undernutrition. Overall, the main conclusion to be drawn from Figure 5.10 is that IYCF practices had little effect on the risk of being stunted, wasted or underweight. IYCF practices were further analysed by residential sectors to see any variations, and results showed that children living in the estate sector had a lower dietary diversity (64.6 per cent) compared with children in the urban (73.1 per cent) and rural (69.5 per cent) sectors. They also had a slightly lower minimum meal frequency (79.5 per cent) than children in urban (81.5 per cent) and rural (83.5 per cent) sectors (Results were not reported).

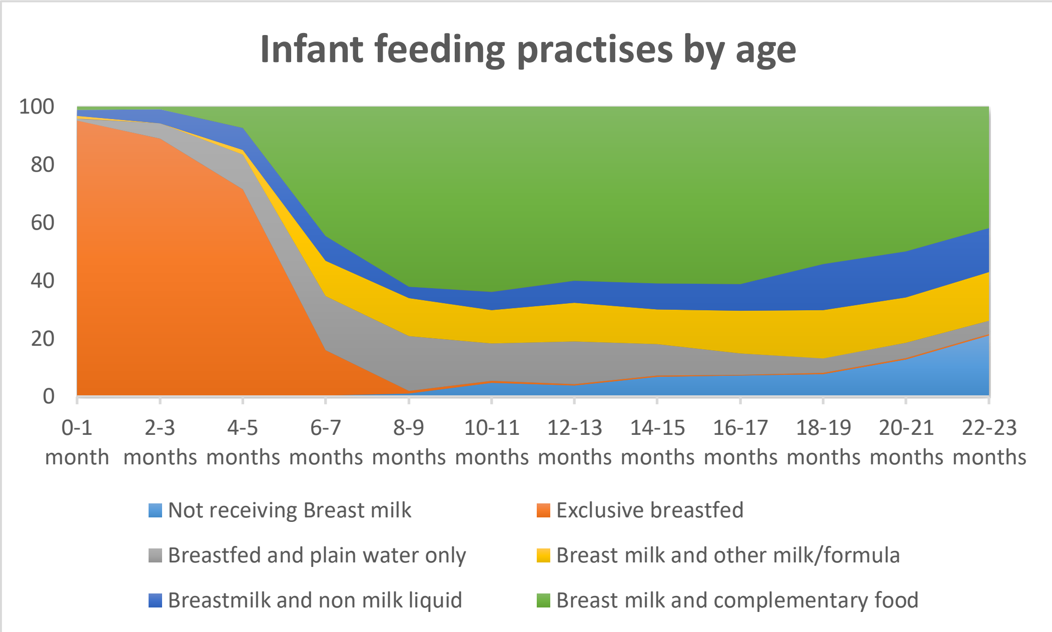
Figure 5.10 Stunting, wasting and underweight rates by feeding practices for children aged 6-23 months (n = 2,286)



5.8.1 Exclusive breastfeeding status and child nutrition status for the children living with their mother born 0 to 23 months before the survey

Figure 5.11 presents the percentage distribution of feeding practices by child's age group. Exclusive breastfeeding is concentrated in the first six months, at which age it is recorded that 84 per cent of children are exclusively breastfed. Exclusive breastfeeding then decreases sharply with the age. After the age of 5 months, the majority of children received complementary foods in addition to breast milk, as recommended. Almost none of the children were reported never to have breastfed.

Figure 5.11 Infant feeding practices of children aged 0-23 months (*n* = 2,990)



To assess the relationship between breastfeeding status and child nutritional status, this study explored a breastfeeding analysis across the different age subgroups 0-23 months, 24-36 months, and 37 months and over. For the children aged 0-23 months, chi-square analysis was carried out to see if there was any association between child nutritional status and whether the child was exclusively breastfed or not. For children aged 24-36 months, since most of them are no longer exclusively breastfeeding, current breastfeeding status was considered. For children aged 37 months and above, nearly all children were no longer breastfed, so the association between the duration of breastfeeding (how many months they were breastfed for) and the nutritional status was analysed. The results are shown in Table 5.14.

According to the results, amongst children aged 0-23 months, there was no significant association between exclusive breastfeeding status and nutritional outcomes. However, current breastfeeding status did have a statistically significant association with nutritional status for children aged 24-36 months. Children who still breastfed were more likely to be stunted, wasted or underweight compared to children that were not breastfeeding. Other indicators related to breastfeeding status were not significant together with the duration of breastfeeding when the child is aged more than 37 months or more.

This study further conducted a multivariate logistic regression analysis (Table 5.15) restricted to the age group 24-36 months to further explore whether the association between breastfeeding and nutritional outcomes held up when other covariates were controlled. This showed that breastfeeding status was no longer significant once educational level, wealth and ethnicity were considered.

Table 5.14 Association between breastfeeding and child's stunting, wasting and underweight status

Age in months	Sample size (n)	Breastfeeding status	Stunted %	Chi square p value	Wasted %	Chi square p value	underweight %	Chi square p value
0-23	2,990	**Exclusive breastfed**	12.2	0.974	15.9	0.574	15.2	0.846
		Not exclusively breastfed	12.1		18.4		14.4	
24-36	1,813	**Currently breastfeeding**						
		Yes	23.4	0.050*	14.7	0.040**	25.5	0.003**
		No	19.6		11.3		19.2	
37 months above	3,157	**Currently breastfeeding**						
		Yes	16.5	0.219	14.9	0.691	23.4	0.233
		No	14.5		15.6		21.3	
		Months breastfed						
		Less than one year	13.9	0.558	13.1	0.152	18.8	0.151
		one to two years	15.7		15.6		20.9	
		Over two years	14.1		16.9		23.0	

Table 5.15 Impact of current breastfeeding status on child stunted, wasted and underweight for children aged 24-36 months (*n* = 1,813)

	Stunted	Wasted	Underweight
Covariate	**Odds ratio (95 per cent CI)**	**Odds ratio (95 per cent CI)**	**Odds ratio (95 per cent CI)**
Currently breastfeeding			
yes	1.00	1.00	1.00
no	0.79 (0.59,1.06)	1.07 (0.75,1.54)	0.82 (0.62,1.09)
Wealth index quintile			
Lowest	1.00	1.00	1.00
Second	0.83(0.56,1.21)	1.01 (0.63,1.60)	0.83 (0.57,1.21)
Middle	0.61(0.40,0.93) *	0.60 (0.35,1.01)	0.61 (0.41,0.91) *
Fourth	0.51 (0.33,0.78) **	0.69 (0.41,1.18)	0.47 (0.31,0.71) **
Highest	0.50 (0.31,0.82) **	0.52 (0.28,0.94) *	0.42 (0.25,0.68) **
Education status			
Up to grade 6	1.00	1.00	1.00
Passed Ordinary Level	0.70(0.41,1.20)	1.96 (0.85,4.53)	1.02 (0.58,1.79)
Passed Advanced Level	0.41 (0.22,0.77) **	1.43 (0.58,3.55)	0.64 (0.34,1.21)
Degree	0.55(0.24,1.28)	0.77 (0.23,2.60)	0.54(0.22,1.33)
Ethnicity			
Sinhala	1.00	1.00	1.00
Sri Lanka Tamil	0.92 (0.63,1.33)	0.49 (0.29,0.84) *	0.70 (0.49,1.02)
Indian Tamil	2.64 (1.39,5.03) **	0.65 (0.24,1.73)	1.45 (0.75,2.81)
Muslims and other	1.22 (0.78,1.88)	0.57 (0.31,1.04)	0.75 (0.48,1.19)

5.9 The association between immunisation status and child nutrition for Sri Lankan for children aged 12-24 months (n=1,516)

Table 5.16 shows the percentage of children aged 12-14 months immunised by the type of vaccine for each age group. The percentage of children, who received recommended immunisation at any time before the survey, according to the immunisation card and mother’s report is impressive for most of the vaccines as it exceeds 90 per cent. Among these children, almost 80 per cent (79.4 per cent) of the children (1,205) were fully immunised, only 20.5 per cent (311) had been partially vaccinated, less than 1.07 per cent (1) had not received any immunisation. Missing cases and children who had not received any vaccinations are removed from the analysis which are accounted for 0.85 per cent of the total, leaving 1,516 children. Determinants of immunisation were investigated and only ethnicity and province (among maternal age, maternal education, residential sector, wealth index) were significantly associated (p<0.05) with immunisation status. About 81.7 per cent of children were from Sinhalese mothers were received full immunisation, whilst partial vaccination was the highest (26.3 per cent) among Sri Lankan Tamil mothers. Also, the highest fully immunised children were reported in Sabaragamuwa Province, whilst partial vaccination was highest among children lived in the North-Central Province (results were not reported).

Table 5.16 Percentage of children immunised by immunisation type for children aged 12-24 months based on child and maternal records* (*n* = 1,516)

Type of immunisation	Year	Frequency	Percentage vaccinated
BCG	0-4 weeks	1,516	100.0
Pentavalent 1	2 months completed	1,492	98.4
Polio 1		1,505	99.2
Pentavalent 2	4 months completed	1,490	98.2
Polio 2		1,494	98.5
Pentavalent 3	6 months completed	1,477	97.4
Polio 3		1,485	97.9
Measles (MMR 1)	12 months completed	1,264	83.3
vitamin A supplementation	6 months completed	1,168	82.7

*To have received all basic immunisation child must receive at least one does of BCG vaccine, three doses of Pentavalent/DPT, three doses of polio vaccine and one does of measles vaccine.

The association between immunisation and child nutrition outcomes was explored (Table 5.17). Data were available for 1,457 children for stunting, 1,450 for wasting and 1,468 for underweight of the total sample of 1,516 for child immunisation status. According to the chance of a child being underweight was associated with the vaccination status (*p* = 0.018).

Table 5.17 Immunisation status by child nutrition status for children aged 12-24 months (*n* = 1,516)

Immunisation status	n	% Stunted	Chi Square P value	n	% Wasted	Chi Square P value	n	% Underweight	Chi Square P value
Fully immunised	1,162	20.6	0.993	1,157	14.2	0.06	1,168	19.6	0.018*
Partially immunised	295	20.6		293	9.9		300	13.6	

Based on the results from the chi-square test, multivariate analysis was further fitted for children who were restricted to 12-24 months old (Appendix I). The analysis was adjusted for key child, maternal, household and residential factors. The effects on being underweight from immunisation given in early in life were confirmed by the adjusted logistic regression, where children who were fully immunised are twice as likely to be underweight compared to children who were partially immunised (AOR = 2.06; 95 per cent CI: [1.31, 3.22]). Child's age, low birth weight status, maternal BMI and height and household wealth were found to be significant predictors in this model. However, the variables related to child morbidity such as episodes of diarrhoea and fever were also not found significant in this model, once controlled for other socioeconomic factors.

To understand if there is any long-term immune response on child nutritional indicators, this study further explored the relationship between immunisation status and nutrition status for children aged 12-59 months. There was not a significant association found between immunisation and children aged 12-59 months.

5.10 Predicted probabilities of stunting in low birth weight children

It is evident from the data that children who were born as LBW babies have a much higher risk of undernutrition compared to normal birth weight babies. The row numbers in all eight possible combinations of stunting, wasting and underweight by LBW were explored and presented in Figure 5.12 and Table 5.18. Among 1,138 LBW children, 8.5 per cent had all forms of undernutrition and 13.9 per cent (158) had both stunting and underweight. Therefore, LBW children who were both stunted and underweight were 255 (22.4 per cent). Of these 97 were wasted as well as stunted.

Figure 5.12 Venn diagram for low birth weight children by stunting, wasting and underweight

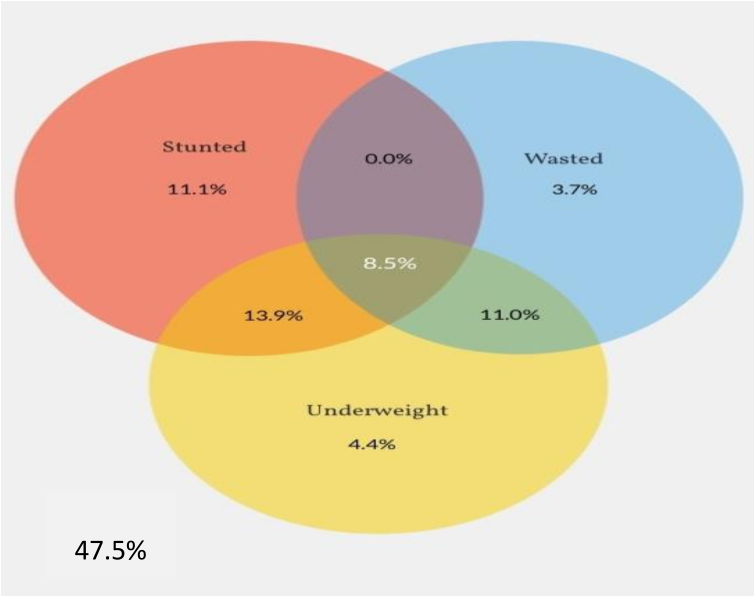


Table 5.18 Low birth weight status by stunting, wasting and underweight (unadjusted percentages) (n = 1,138)

Birth weight status by stunting, wasting and underweight			**LBW children** n (%)	**Normal birth children** n (%)	**Total**
Stunted	Wasted	Underweight	97 (8.5)	119 (2.4)	216
Stunted	Not wasted	Underweight	158 (13.9)	329 (5.9)	487
Stunted	Not wasted	Not underweight	126 (11.1)	386 (6.9)	512
Stunted	Wasted	Not underweight	0 (0.0)	0 (0.0)	0
Not stunted	Wasted	Underweight	125 (11.0)	345 (6.1)	470
Not stunted	Wasted	Not underweight	42 (3.7)	249 (4.4)	291
Not stunted	Not wasted	Underweight	50 (4.4)	147 (2.6)	197
Not stunted	Not wasted	Not underweight	540 (47.5)	3,996 (71.7)	4,536
Total number of children			1,138 (100.0)	5,571 (100.0	6,709

The bivariate and multivariate analysis results of the child nutrition indicators also show LBW as a strong predictor; LBW children were more likely to be stunted, wasted and underweight even after controlling for other children, maternal, household residential covariates. To find out whether LBW children are able to catch up with the growth in later ages, predicted probabilities of stunting were calculated by birth weight status using the final multivariate logistic regression model for different age groups of children aged 6-59 months.

The predicted probabilities of stunting and underweight are shown in Figure 5.13 and 5.14. Predicted probabilities of stunting for LBW children increase for the first two and half years and then decrease after 36 months, exhibits a recovery from stunting between ages three and five.

Predicted probabilities are comparatively low for normal birth weight children with a declining trend. For underweight, predicted probabilities of LBW increase up to age 48 months then show a decline.

Predicted probabilities of stunting also explored across the wealth quintiles (Figure 5.15) and the children in the lowest wealth group has the highest predicted probabilities of being stunted, whilst children in the wealthiest category have the lowest predicted probabilities across the age groups.

Figure 5.13 Predicted probabilities of stunting by birth weight status

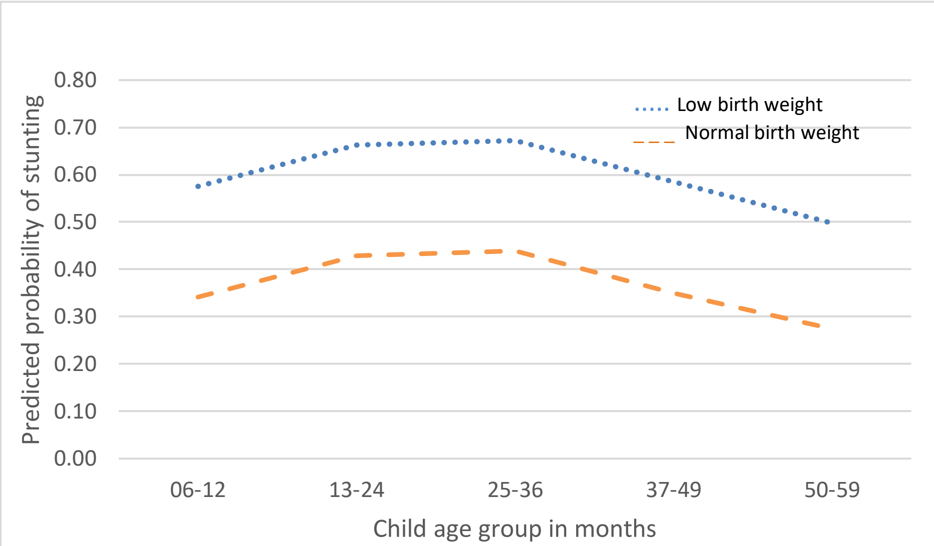


Figure 5.14 Predicted probabilities of underweight by birth weight status

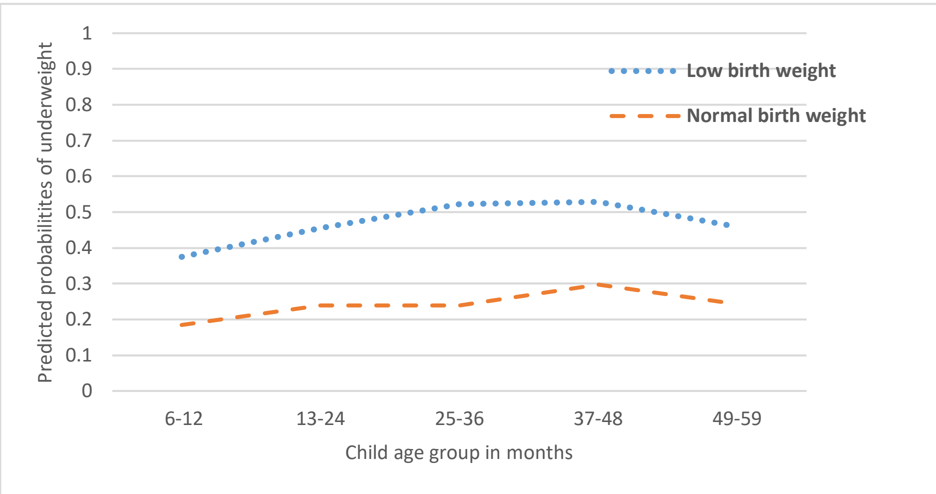


Figure 5.15 Predicted probabilities of stunting by wealth quintiles

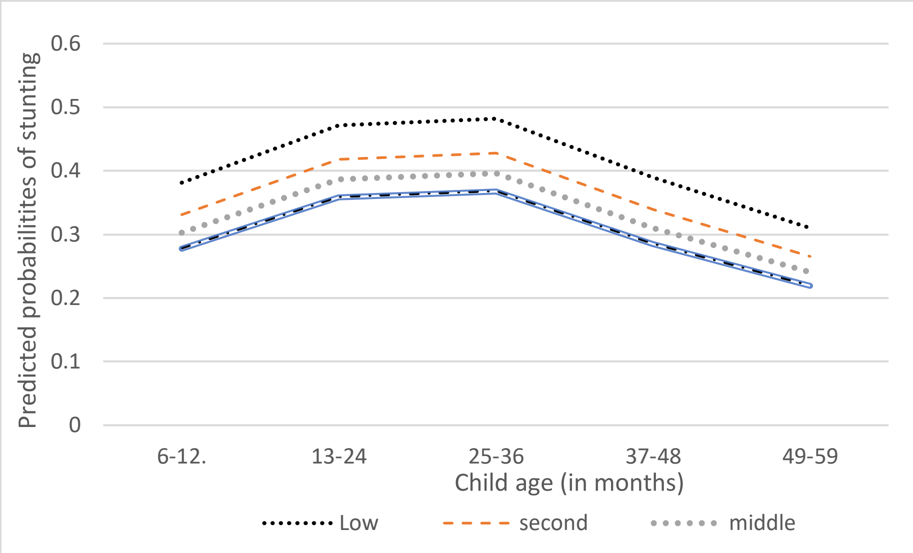


Table 5.19 presents the consolidated results of Model 3 of each child undernutrition outcomes in the multivariate logistic regression analysis. The +sign indicates a covariate with significant positive impact and a – sign indicates significant negative impact.

Table 5.19 Summary table for all final models of child undernutrition outcomes

	Stunting	Wasting	Underweight
Variables	**AOR (95%CI)**	**AOR (95%CI)**	**AOR (95%CI)**
Birth weight			
Normal (>2500 gms) (Ref)			
Low birth weight (≤2500 gms)	+	+	+
Age (in months)			
6-11 (Ref)			
12-47	+		+
48-59			
Birth interval			
First birth (Ref)			
< 24 months		+	
24-47 months	+	+	+
48+ months		+	
Child morbidity status			
None (Ref)			
Had diarrhoea/cough/fever		+	
Maternal BMI			
Thin (<18.50)		+	+
Normal (18.50-24.99) (Ref)			
Overweight (25.00-29.99)		_	_
Obese (≥30.00)	_	_	_
Maternal height			
Short (≤145 cm) (Ref)			
Average (145.01-155.0 cm)	_		_
Tall (155.01+)	_		_
Maternal education			
Grade 5 or below (Ref)			
Grade 6 to O level			
Advanced level			
Degree and higher		_	_
Ethnicity			
Sinhalese (Ref)			
Sri Lankan Tamil			
Indian Tamil	+	_	
Sri Lankan Moor/Muslim	+	_	
Household wealth quintile			
Lowest (Ref)			
Second	_		
Middle	_		_
Fourth	_		_
Highest	_		_
Province			
Western (Ref)			
Central	+		
Southern			
Northern			
Eastern			
North-Western			
North-Central			
Uva			
Sabaragamuwa			_

5.11 Summary of key findings

This section summarises the results of the second paper; the findings are discussed in Chapter 5 of this thesis.

- Regarding the first research question proposed by this analysis chapter, in identifying determinants of child undernutrition outcomes, the fixed-effect logistic regression results showed that child's age, birth weight status, mother's body mass index (BMI), and maternal stature, wealth quintile, and source of drinking water had significant associations with stunting. Findings also reported that children living in poor households, born to Indian Tamil mothers in the estate sector have higher risks of stunting than their counterparts in other sectors.
- In terms of child wasting, the same factors were found to be significant, except for maternal height, wealth index and the province. In addition, child morbidity and maternal education status were associated with child wasting.
- This study further found similar results for child underweight among children under age 5 years. However, ethnicity was not found significant, while maternal education was significant once all factors were considered in the underweight model. In addition, the availability of livestock and using traditional cooking fuel have increased the risk for child underweight.
- The results showed that concentration index values were negative for each outcome, confirming socioeconomic inequalities in child undernutrition outcomes, with these outcomes being more common in poorer households. The highest inequality was observed among child stunting followed by child underweight.
- The effect of child feeding practices on child nutrition outcomes was not strong. Current breastfeeding for children aged 24-36 months, had increased odds of being undernourished, however, the effect was not strong once controlled for other variables.
- Children who received all recommended immunisations during the first year of life was associated with an increased risk of underweight, compared to having partial vaccinations. For example, children aged 12-24 months, who are fully immunised had higher odds of underweight compared to children who had partial immunisation. However, the effect was not significant when the child age range was expanded to 12-59 months.

- Results from the predicted probabilities of low birth weight children have exhibited a recovery from stunting between ages three and five.

- Results from the three-level random intercept models were similar to fixed- effect models; however, the effect of some factors has increased such as low birth weight.
- There was a relatively little variation at the community level on child undernutrition outcomes, however, there was more variation between households within the same community on child undernutrition outcomes. This is perhaps a reflection that children living in the same households have substantial correlated unobserved factors that affect their nutritional status.

  The next chapter explores how child stunting coexists with maternal overweight and obesity at the household level, and which risk factors may influence this paradoxical situation. This will be explored through undertaking analysis of various individual, maternal household and residential factors.

5.12 Strengths and limitations

The strengths of the present study include the use of child anthropometric data from the most recent population-based representative survey in 2016-2017 that covered the whole island for the first time after the civil conflict ended in 2009. This study applied methods of adjustment for the sampling weights suggested for the DHS data. The exclusion of under 5 months children was another advantage of this study, as 6-59 months of age assumes to be critical for reflecting child development, avoiding any errors that could be raised when using baby-weighing instruments for small babies. Likewise, the application of random intercept models, considering the nested structure of the data, made it possible to disentangle the effects of the individual and contextual effect on child undernutrition. To the best of our knowledge, none of the studies on child undernutrition accounted for this. Another limitation is that, due to the cross-sectional study design, it was difficult to establish causal relationships between different variables. This study used anthropometric cut-offs according to the WHO child growth standards. However, it is suggested that WHO growth standards may not necessarily reflect optimal growth patterns in populations Sri Lanka (Rannan-Eliya et al., 2013), as their inability to quantify the genetic influence that could lead to child growth variations. Also, the unavailability of data on some potential confounders, particularly community variables such as distance to access the health services, childcare and taboos of dietary practices could affect the quality and accuracy of the findings.

Chapter 6 The double burden of malnutrition: the coexistence of stunted children and overweight and obese mothers in Sri Lanka

6.1 Abstract

Background: Sri Lanka has been experiencing a persistently high prevalence of child undernutrition and a steady increase in overweight and obesity among women, along with a rise in non-communicable diseases. This situation has emerged as a “double burden of malnutrition”, which has not been systematically investigated in Sri Lanka.

Aim: To examine the risk factors associated with the double burden of malnutrition (DBM) in Sri Lanka at the household level.

Methods: Multinomial logistic regression was used to estimate the risks of stunted child-overweight/obese mother pairs after adjusting for selected individual, socioeconomic and geographic factors.

Participants: The analysis sample considered 5,975 mother-child pairs living within the same households, who had their complete anthropometric measurements.

Outcome: We used the height-for-age Z-score (stunting) for children and body mass index (BMI) for mothers as primary outcome measures. The presence of both, child stunting and maternal overweight or obesity in the same household was classified as “double burden” pairs.

Results: It is revealed that DBM within the same household is emerging as a trend in Sri Lanka. Data showed that the coexistence of child stunting and overweight mother in Sri Lanka was 8.3 per cent, and the stunted child and obese mother pair was 2.8 per cent. Child’s age, low birth weight status, maternal age, increased household members, delivery mode, wealth status, ethnicity and the residential province were significantly associated with double burden pairs. Ethnicity was a significant risk factor explaining the coexistence of DBM, as Muslim mothers have an elevated risk of being in a double burden child-mother pair.

Conclusion: DBM is an emerging and significant nutritional challenge in Sri Lanka. Appropriate actions should be taken simultaneously to reduce both child stunting and maternal overweight burdens rather than addressing them as separate public health issues.

Key messages

- The double burden of malnutrition is an emerging nutrition challenge in Sri Lanka, there are 8.3 per cent of stunted child-overweight mother pairs and 2.8 per cent stunted child-obese mother pairs at the household level.
- Factors such as child's age, low birth weight status, maternal age, increased household members, delivery mode, wealth status, ethnicity and the province are significantly associated with the coexistence of child stunting and mother overweightness and obesity.
- Nutritional policies should be more aligned to address both child undernutrition and increasing overweight and obesity of mothers.

6.2 Introduction

The double burden of malnutrition (DBM) is defined as the coexistence of both undernutrition along with overweight and obesity. The prevalence of DMB and its impact on diet-related non-communicable diseases (NCDs) across the life course is a global public health concern (World Health Organization, 2018a).There are multiple forms of malnutrition coexisting at the global, regional, country and household level. It has been evident that, globally, nearly one in every three persons suffers from at least one form of malnutrition, and it is reported in 2014, approximately 2.01 billion adults were either overweight or obese while 462 million were underweight (World Health Organization, 2018a). In the same year, among children aged under five years, 42 million were found to be overweight or obese while 150.8 million were affected by stunting (Doak et al., 2016; World Health Organization, 2018a).

An increasing amount of literature has demonstrated that the population in low, and middle-income countries (LMICs) has undergone various levels of nutrition transition, including rapid shifts in dietary patterns, lifestyles along with a sequence of social, demographic and economic changes (Jehn and Brewis, 2009; Popkin, 2003). The rapid transition has led to a global increase in obesity and NCDs characterised by increased health gaps among poor and marginalized populations. Despite the persistent problem of undernutrition in LMICs, these countries now face a unique situation with the two worst forms of malnutrition; while infants and children struggle with undernutrition, adults face a higher prevalence of overweight or obesity (overnutrition), often at the individual level or within the same household (World Health Organization, 2018a).

This phenomenon seen in LMICs has gradually exceeded the rates reported in high-income countries (HIC) (Popkin et al., 2020; World Health Organization, 2018a).

Sri Lanka, as a country among the LMICs, is not an exception but continues to be confronted with high and stagnated rates of undernutrition with increasing rates of adult overweight and obesity. There is new evidence that reports an increase in the incidence of DBM at the household level (Shinsugi et al., 2019). In this context, the present study seeks to examine the patterns of DBM and more specifically coexistence of stunted children with overweight and obese mothers at the same households in Sri Lanka, using data from the 2016 Demographic and Health Survey.

6.3 Drivers of Double burden of malnutrition

The double burden of malnutrition or the concurrent undernutrition and overnutrition within the same population, same household or even individual is related to a series of nutrition, demographic and epidemiologic transformations occurring globally (Shrimpton, 2012). According to the literature, the main causes of the DBM link to a sequence of changes known as the nutrition transition, the epidemiological transition, and the demographic transition. The relationship between these transitions and the nutrition transition is illustrated in Appendix J, based on Popkin (2002). Nutrition transition describes the changes in the dietary patterns, consumption and energy intake associated with the rapid economic development over time. People need energy, and they consume a large amount of processed food, including more saturated fat, carbohydrates (including sugar), and salt. The national food policies tend to subsidize these items, so they are affordable but can also contribute to overconsumption of food rather than a balanced diet. These dietary changes happen simultaneously with a decline in physical activities with an increase in sedentary activities and the use of labour-saving equipment at the household level. These behavioural changes are associated with a shift from a greater prevalence of undernutrition in the population towards an increase in overweight, obesity and NCDs (Griffiths and Bentley, 2001; Popkin et al., 2012; World Health Organization, 2018a). In the demographic transition, there is a change from high fertility and mortality to declining fertility and mortality trends. This transition is often linked with changes in the age structure with an increase in the proportion of elderly people who are vulnerable to NCDs. With the increase in the levels of human migration and mobility as seen in the last three decades, there is also a rapid expansion of population living in urban areas with more pre-disposed income and access to facilities thus spurting increasingly sedentary lifestyles and risk behaviours. As for the epidemiological transition, the focus is on the shift in disease patterns from a situation dominated by infectious diseases related to malnutrition (malaria, diarrhoea, measles, etc.) to one dominated by more man-made, nutrient-related chronic and degenerative diseases (NCDs) (Omran, 2005; Popkin, 2003; World Health Organization, 2018a).

According to the WHO, these transitions are integrated and reflective in intergenerational changes, particularly in middle-income or transition countries. For instance, these transitions happen over the years, resulting in intergenerational changes in diet quality and quantity for individuals and for the population as a whole. This leads to a coexistence or overlap of overweight and undernutrition at the population level. Moreover, these changes even result in obesity in individuals who were stunted during their childhood, reflecting a shift in food practices, diet and behaviours over decades (World Health Organization, 2018a).

This coexistence of over, and under-nutrition, sometimes termed ‘paradoxical’ malnutrition at the household level was defined as one or more individuals with wasting/stunting/thinness and one or more individuals with overweight/obesity within the same household. This can happen in one of four ways; 1) the child is stunted and overweight; 2) the mother is overweight and one of her children under 5 is wasted; 3) the mother is overweight and one of her children under age five is stunted; or 4) the mother is thin and one of her children is overweight (Popkin et al., 2020). These “dual burden households” seem rapidly emerging to become a major public health burden in LMICs (Jehn and Brewis, 2009; Lee et al., 2010), which is primarily determined by the combination of women with overweight and children with stunting (Doak et al., 2005; Lee et al., 2010; Popkin et al., 2020).

Both undernutrition and overnutrition have health and long-term consequences at individual and wider, society levels (Masibo et al., 2020). For example, a child with chronic malnutrition or childhood stunting is at higher risk of impaired cognitive and physical development, reduced productivity and poor health that could affect economic productivity in adult life. Factors associated with child undernutrition are discussed in Chapter 2, under section 2.2, p. 17-20. On the other hand, individuals with overweight and obesity have an elevated risk of NCDs including hypertension, coronary heart disease, diabetes, stroke, raised blood pressure, high lipid profiles and some forms of cancer, that could lead to obstruct economic productivity and increase expenditure on health care (Doak et al., 2005; Sunuwar et al., 2020; World Health Organization, 2018c).

According to World Health Organization (2018), the coexistence of undernutrition and overweight or obesity happens across the life-course (Wells et al., 2020; World Health Organization, 2018a). Poor maternal nutrition prior to or during the pregnancy has an increased risk of having low birth weight children; these children are at an elevated risk of being undernourished, and in long term, these children with a low birth weight (LBW) or other nutritional deficiencies are more vulnerable to develop obesity in their later life which may lead to the continuation of the prevalence of stunted child-overweight mother (SCOWT) pairs (Dieffenbach and Stein, 2012). On the other hand, despite the vulnerability of having NCDs, being overweight or obese during pregnancy increases the risk of several adverse maternal and fetal complications, such as gestational diabetes during pregnancy (Stubert et al., 2018; Zheng et al., 2018) and may have newborns with excess size and birth weight, who can be at risk of obesity in later life (Stubert et al., 2018; Zheng et al., 2018).

The relationship between child stunting, maternal overnutrition and the subsequent risk of obesity in childhood malnutrition is elaborated in the medical literature (Aitsi-Selmi, 2015; Lee et al., 2010). Barker (2012) postulated a Fetal origin hypothesis, that maternal nutritional status during pregnancy is vital as it could 'program' the foetus for the potential development of chronic disease when in adulthood (Barker, 2012). The hypothesis is subsequently modified as the 'Developmental Origins of Health and Disease (DOHaD)' hypothesis, which postulates how the environment influences before birth and the growth of early life, cause short-term and long-term health consequences. This includes nutrition, exposure to toxic stress and environmental chemicals which influence lifelong risk for chronic diseases like obesity, hypertension and diabetes (Barker, 2007; Mandy and Nyirenda, 2018). DOHaD can be applied to the nutrition transition in developing countries that are experiencing a rapid increase in deaths due to NCDs and at the same time struggling to reduce child undernutrition and infectious diseases. Evidence from these countries showed that maternal undernutrition during pregnancy and early childhood may predispose to an elevated risk of having obesity and NCDs such as diabetes, metabolic syndrome, and CVD later in life if they are exposed to high-calorie foods, unhealthy diets and lack of physical activities (Corvalán et al., 2007; Law et al., 2002; Uauy et al., 2011).

The World Health Organization (2018) argues that DBM needs further investigation as it reflects a unique opportunity to understand and integrate actions to contain all forms of malnutrition. Hence, addressing DBM is acknowledged as a global priority, integrated with the Sustainable Development Goal 2 and the commitments of the Rome Declaration on Nutrition, within the United Nations Decade of Action on Nutrition (Amugsi et al., 2019; United Nations, 2017, pp. 14-15; World Health Organization, 2018a).

6.4 Double burden of malnutrition in Sri Lanka

According to the United Nations World Food Programme (2018), Sri Lanka is currently facing a double burden of malnutrition with stagnant rates of child undernutrition combined with growing numbers of overweight and obese people (World Food Programme, 2018).

Despite improvements in child and maternal health and life expectancy indicators, Sri Lanka has not made satisfactory progress in reducing child undernutrition as expected. Child undernutrition rates have stalled; the proportions of children stunted, wasted and underweight are reported as 17 per cent, 15 per cent, and 21 per cent respectively in the last two decades, while, at the same time, the prevalence of maternal overweight and obesity has also soared from 2006 to 2016. The recent 2016 Demographic and Health Survey (DHS) in Sri Lanka examined the national magnitude of overweight and obesity among women. The survey reported 32 per cent of women as overweight and 13 per cent as obese, which was nearly a twofold increase compared to the earlier 2006 DHS. The mean body mass index (BMI) for ever-married women aged 15-49 years has also increased from 23.1 to 24.8 during the decade 2006-2016 (Department of Census and Statistics, 2017). Thus, child malnutrition and maternal obesity constitute a serious public health emergency in Sri Lanka (Shinsugi et al., 2019).

The DBM is often linked to the simultaneous phenomena of nutritional transition, epidemiological transition and demographic transition, and the health outcomes within each of these transitions often overlap (Popkin et al., 2012).

Sri Lanka was pioneering in its demographic and epidemiological transitions, being among the countries that reached replacement level fertility quite early compared to other low-income countries. Sri Lanka has set foot in the third stage of demographic transition and is approaching the final stage. As such, Sri Lanka's life expectancy has increased with an increase in the share of the elderly population, and fertility rates have declined (see Chapter 1 for more details). New health challenges related to NCDs are rapidly emerging within the country. For instance, NCDs have risen to comprise 83 per cent of deaths, and nearly one in five people die prematurely from NCDs, adult obesity being found to be a key risk factor of the mortality profile (World Health Organization, 2018d).

Sri Lanka also has been experiencing a rapid socioeconomic transition over the last three decades. Changes in income levels are also pronounced; the country recently moved to the group of the upper-middle-income group with a gross domestic product (GDP) of $4,095 per capita income in 2018. According to recent data, Sri Lanka is in the third stage of the nutrition transition characterised by a change in lifestyles towards sedentary behaviour, a high female labour force participation rate and the rapid emergence of the processed food industry. For instance, female labour force participation increased from 32.8 per cent in 2012 to 35.44 per cent in 2019, the urban population grew from 16.4 per cent to 18.4 per cent between 1960 and 2016 and the percentage of people employed in the agriculture sector (predominantly labour-intensive) decreased from 32.5 per cent to 25.7 per cent during the decade 2009-2019 (Somasundaram et al., 2019).

As it has been reported from previous studies that Asian countries dietary patterns have been shifted from a traditional diet to an energy-dense, nutrient-poor diet dominated by processed food higher in fats, sugar and salt. Thus, Sri Lanka has not been an exception, which has been undergoing rapid changes in the shift in food patterns.

Along with rapid economic growth, the nutritional practices of Sri Lankan households have markedly shifted towards unhealthy dietary patterns which are high in fat and refined carbohydrates (Rathnayake et al., 2013). People tend to replace vegetable-based foods with animal products to gain energy, protein and fat (Weerahewa et al., 2018; Weerasekara et al., 2018; Wijesekere, 2015). For instance, vegetable and fruit consumption has been dropped over the last decades, even below the recommended level (Weerahewa et al., 2018). In addition, the daily sugar salt and alcohol intake exceeded the recommended daily consumption exposing numerous health risks (Weerahewa et al., 2018). The Sri Lankan traditional food system which is characterised by a range of indigenous cereals, fruits and vegetables which are directly associated with reducing health risks, tends to be dominated by western fast foods, so the population is in jeopardy with numerous health threats including the rapid rise of NCDs (Weerasekara et al., 2018). Notwithstanding the dietary changes, the mushrooming of global food chains such as Pizza Hut, Kentucky Fried Chicken and McDonald's throughout the country has accelerated the nutritional transition in Sri Lanka (Institute of Poverty Analysis, 2018; Jayawardana et al., 2017; Rathnayake et al., 2013; Somasundaram et al., 2019). Dietary patterns among Sri Lankan children also have been changed over time, as they are likely to consume inadequate fruits and vegetables with excessive intakes of sugary snacks and inactive behaviours such as watching television while eating the evening meal (Sirasa et al., 2019).

Recent studies in Sri Lanka have paid much attention to understand the prevalence of obesity and it is found that obesity was prominent among Muslims, among the most educated group (above A/Level) and in urban settings (Jayasinghe et al., 2020; Katulanda et al., 2010; Somasundaram et al., 2019). Muslims had the highest prevalence of all three obesity (overweight, obese and abdominal obesity) categories (De Silva et al., 2015). The dietary diversities were assessed, and it is revealed that children or adults belonging to the Muslim ethnicity have the highest dietary diversity compared to other ethnic groups. For instance, Muslims are reported to have the highest daily energy intake (kcl) of 1748.8 whilst Indian Tamils have the lowest of (1437.7 Kcal/d). Similarly, the mean daily protein intake was highest for Muslims (52.2 g) compared to others

(Jayawardena et al., 2014). However, little is known of how dietary patterns and their association with double burden pairs in the households.

Overall, nationally representative data on the DBM are very limited and nothing much has been done to investigate the double burden of undernutrition and overnutrition at the household level, examining both outcomes together using child-mother pairs. One study aimed to explore the DBM of mothers and primary school children by socioeconomic status in urban Sri Lanka found that socioeconomic inequalities combined with maternal nutrition affected child malnutrition (Shinsugi et al., 2019). This study further found a positive correlation between maternal BMI and children's BMI, where overweight and obese mothers were less likely to have thin children. Further, it is found that maternal employment status and household income were marginally associated with childhood overweight and obesity (Shinsugi et al., 2019). Studies on investigating DMB or associated factors such as child stunting or maternal obesity were all conducted in specific settings (specific districts, urban settings) or among specific population groups (pre-school children), and not at the national level.

Thus, the main objectives of this study are to identify factors associated with DBM; the existence of child stunting and maternal overweight and obesity in the same household as a whole and to identify maternal and child dietary patterns and investigate their associations with DBM.

6.5 Factors associated with DBM at the household level

This section describes the various interlinked factors of household malnutrition. Although research is limited, an increased prevalence of DBM at the household level is discussed in the studies conducted in LMICs, including Asia, Latin America and Africa (Dieffenbach and Stein, 2012; Garrett and Ruel, 2005; Kapoor and Anand, 2002; Tzioumis and Adair, 2014). Particular attention is given to the factors associated with the DBM at the household level or the paradoxical child-mother pairs; stunted child-overweight mother pair (SCOWT) or stunted child-obese mother pair (SCOB).

6.5.1 Child characteristics

Child characteristics associated with DBM are reported in some studies. These characteristics include the child's age, low birth weight, sex of the child and longer birth intervals. As documented in a study conducted in Bangladesh and Indonesia, a child being a female and having an older age are associated with the maternal and child double burden (MCDB) (Oddo et al., 2012). This finding is consistent with a study in Guatemala, as among discordant mother-child pairs (stunted child-overweight mother), the majority (55.3 per cent) were reported as female

(Lee et al., 2010). The nutrition indicators globally reported that girls are at an increased risk of being stunting, due to poor feeding and nutrition practices compared with boys. This may derive from social norms and discriminatory attitudes and practices towards girls (Oddo et al., 2012; UNICEF, 2009). Various studies have found that breastfeeding is protective against the DBM (Oddo et al., 2012). A number of other children in the household also found as a risk factor for DBM, as it directly impacts the availability of food to the target child (Jehn and Brewis, 2009). Studies also found that children who are currently breastfeeding tend to have lower undernutrition rates and breastfeeding also helps to tackle maternal obesity for mothers who gained excess weight during their pregnancies (Anik et al., 2019; Hoffman et al., 2019; Oddo et al., 2012). For instance, it is reported that mothers who have reduced or stopped breastfeeding are more likely to be overweight and obese (Bever et al., 2015). On the other hand, in a context where calorie intake is limited, demand for feeding the children can be increased, and this can lead to child weight gain as opposed to maternal weight loss.

6.5.2 Maternal bio-behavioural, social and economic factors

Maternal factors, including maternal age, maternal stature, marital status, education, and employment status, can influence both maternal and child nutritional status (Doak et al., 2005; Hauqe et al., 2019; Jehn and Brewis, 2009; Lee et al., 2010). Studies conducted in different socioeconomic contexts found that mothers who were of an advanced age (mother aged over 35 years), short stature and who had achieved at least secondary level education were more likely to suffer from the DBM (Amugsi et al., 2019; Jehn and Brewis, 2009; Mahmudiono et al., 2019; Oddo et al., 2012; Raphaël et al., 2005).

Maternal education has a strong association with child stunting. According to Jehn and Brewis (2009), paradoxical SCOWT pairs were less likely to occur in households where mothers had formal education compared to those who had no formal education (Jehn and Brewis, 2009). The mother’s employment sector has also been found to be a risk factor, particularly for the child undernutrition status. For instance, children whose mothers engaged in agriculture and manual work had higher odds of being stunted than the children of mothers engaged in professional work (Nankinga et al., 2019). It has also been demonstrated that a mother’s current marital status affects both their own and their children’s malnourishment status. It is found that malnutrition is higher among divorced or separated women compared with married women (Mihretie, 2018).

Considering the economic status, studies revealed that the low socio, economic status of the household is highly entangled with SCOWT pairs. Among LMICs, a study conducted using DHS data found that the prevalence of SCOWT pairs was mostly seen in low/middle-income households in

India, Egypt (Africa), and in Bolivia, Guatemala, and Peru (Latin America) (Doak et al., 2016; Dubois et al., 2011; Garrett and Ruel, 2005; Monteiro et al., 2004). With the rapid economic changes, these countries experience a transition from a traditional, nutritious diet to a high-fat diet with dietary diversity and fewer physical activities. As Kulkarni (2018) pointed out, economic progress often led to an obesogenic environment, some household members including mothers could gain weight, predisposing overweight and obesity. Some evidence further suggests a correlation between food insecurity, poverty with a socioeconomic gradient of overweight and obesity prevalence in many LMICs including Guatemala and Mexico (Doak et al., 2016; Lee et al., 2010; Monteiro et al., 2004; World Health Organization, 2018a). Apart from socioeconomic factors, studies conducted in different contexts including South Asia and South East Asia revealed that increased number of family members is associated with DBM coexistence (Das et al., 2019; Oddo et al., 2012). For instance, a household with more than four members is associated with the prevalence of DBM coexistence in countries such as Bangladesh, India, Nepal, Pakistan, Myanmar, Timor, Maldives, and Cambodia (Biswas et al., 2019). Increased consumption of nutrient-poor and energy- dense food for all members of the household may contribute to increase overweight in adult, however, may be inadequate to meet young children's linear growth potentials (Tzioumis and Adair, 2014).

Apart from these factors, it is found that DBM is associated with Caesarean delivery as the latter has an elevated risk of weight gain among mothers (Ramos et al., 2015).

6.5.3 Community/residential factors

Apart from child and maternal socioeconomic factors, residential factors influence the DBM at the household level. There is some evidence that SCOWT pairs are more visible in the urban areas than rural areas, particularly for the countries such as Bangladesh, Nepal, Pakistan, and Myanmar (Anik et al., 2019). These pairs are mostly seen in affluent households in urban residences, thus they have ample food accessibility with increased dietary diversity (Garrett and Ruel, 2005). On the other hand, some studies argued that SCOWT pairs are seen in rural household settings, particularly in Africa, where rural areas are characterised by a lack of livelihood opportunities, poor access to water, sanitation, a rise in the use of street food and poor child feeding and care practices (Kimani-Murage et al., 2015). Popkin (2003) added that it is not so much urban residence *per se*, but the lifestyle factors associated with an urban environment, that lead to the DBM (Garrett and Ruel, 2005; Popkin, 2003). Nevertheless, it is suggested that nutrition programmes to prevent DBM should be implemented in both rural and urban area (Islam et al., 2019).

In addition, many studies highlighted the link between the dietary diversity of the mother and her child and their nutritional status (Aitsi-Selmi, 2015; Ihab et al., 2013). Countries who are undergoing the nutrition transition could experience rapid changes in food consumption patterns, and food habits over time. These changes characterised by a shift from a nutritious diet towards a westernized, high-calorie diet, consists of refined grains, meat, dairy products, and edible oils. The consumption of energy-dense foods, associated with sedentary and convenient lifestyles of adults may increase the risk of obesity in adult women, whereby a higher energy intake alone may not be effective in preventing child stunting. For example, child who has the higher energy intake often receive energy from fat, intakes of sodium, dietary fibre, folate, and iron. However, these children are not taking nutrient- dense foods, and have the inadequate recommended intake of carbohydrate, vitamins C and D, calcium, and servings of fruits and milk/dairy products that are required for linear growth and weight (Mohd Shariff et al., 2016). This is also evidenced from a study in Egypt, that sugary snack consumption was associated with an increased odds of belonging to a SCOB (stunted/obese) household compared with normal/non-obese pairs, while fruit/vegetable consumption was associated with lower odds of having a SCOB pair (Aitsi-Selmi, 2015).

6.6 Objectives and research hypotheses of the study

The DBM at the household level has hardly been discussed in the South Asian context, in contrast to the marked attention given to Latin American countries (Hossain et al., 2020; Popkin et al., 2020). Studies based on the small-scale community-based samples found inconsistent risk factors associated with DBM at the household level (Anik et al., 2019; Hauqe et al., 2019). This chapter aims to identify the range of individual, maternal, household and residential level risk factors that could affect the coexistence of undernutrition and overnutrition among child and mother pairs at the households in Sri Lanka.

The purposes of this study are, first, to examine how individual, maternal, household and residential factors are associated with DBM, more specifically the existence of child stunting and maternal overweight and obesity in the same household as a whole; and second, to additionally explore the factors associated with women's overweight and obesity and then, to examine the association between the dietary patterns of mothers and children and SCOWT pairs.

This study has the following objectives.

- To examine the risk factors associated with the coexistence of child stunting and mother's overweight and obesity or DBM within the same household.
- To examine factors associated with maternal overweight and obesity.
- To examine the association between child and maternal dietary patterns and the prevalence of DBM.

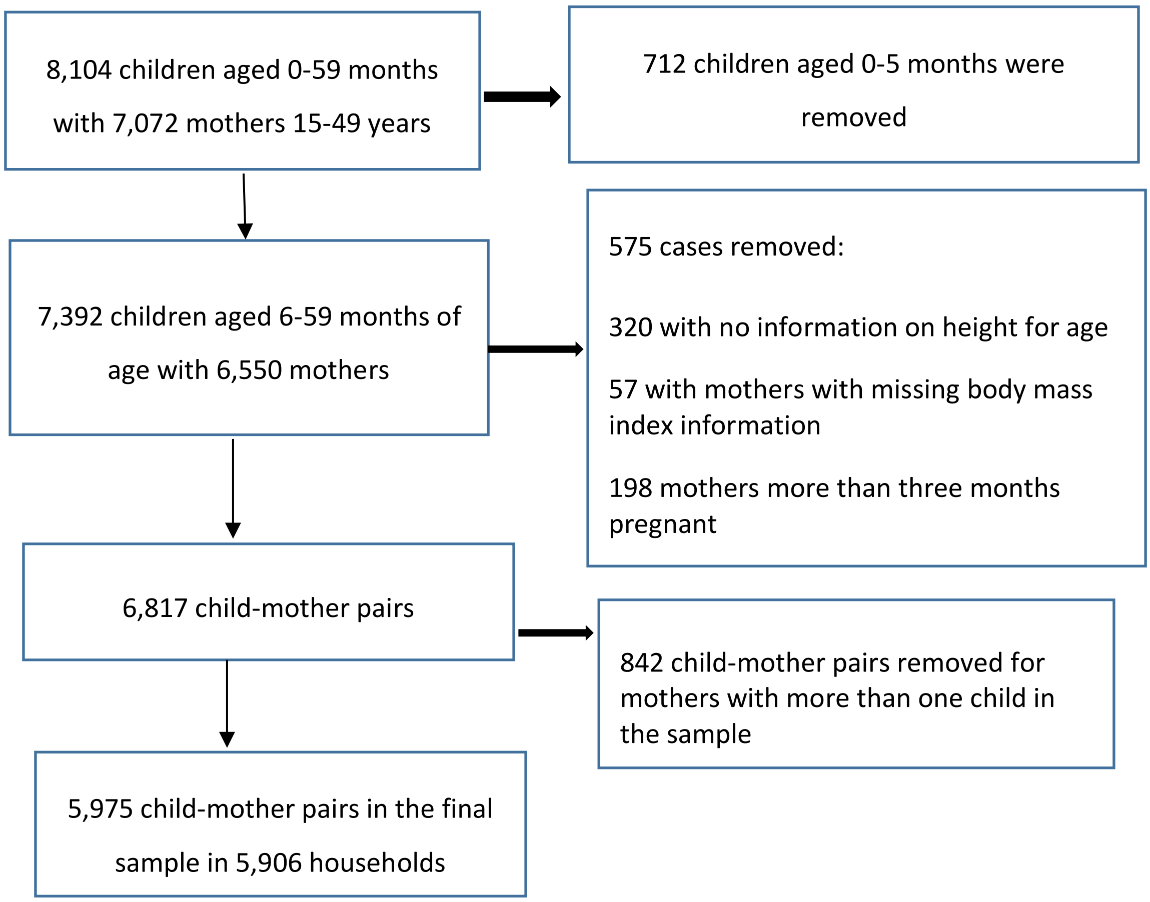
6.7 Data and methods

6.7.1 Data source and sample

This study uses data from the 2016 Sri Lanka Demographic and Health Survey (SLDHS). Detailed information on the DHS survey in Sri Lanka is described in Chapter 3, section 3.2. This study analysed the SLDHS children recode file, which gathered information on all children aged under five years and mothers between the ages of 15 and 49 years. Based on information gathered in the woman's questionnaire, such as children's and mother's anthropometric measures, as well as household socioeconomic and demographic characteristics, this dataset had one record for each child of each interviewed woman.

Out of 6,642 households, a total of 8,104 children aged 0-59 months from 7,072 mothers aged 15-49 years were identified in the recode file. From these, 712 children (8.7 per cent) aged 0-5 months were removed and for the reason excluding 0-5 months children is elaborated in Chapter 7, section 7.3.2. Therefore, the sample included children in the age range 6-59 months. There were 7,392 singleton children aged 6-59 months to 6,550 mothers. Of this subset, we further excluded 575 cases: 320 children who had no information on height for age, 57 mothers who had missing BMI information and 198 mothers who were more than 3 months pregnant as longer-term pregnancies could influence the precision of BMI measures (Jehn and Brewis, 2009). This yielded 6,817 child-mother pairs and, among these pairs. If a mother had more than one child in 6-59 months age group, then we selected only the youngest child for the analysis because of the close nutritional relationship with his or her mother (Dieffenbach and Stein, 2012; Faber et al., 2005). This restriction resulted in 5,975 cases of child-mother pairs (Figure 6.1). From 5,975 cases, we eventually considered 3,470 child-mother pairs based on the categorisation described in section 6.8.2.

Figure 6.1 Distribution of the sample



6.7.2 Types of child-mother pairs

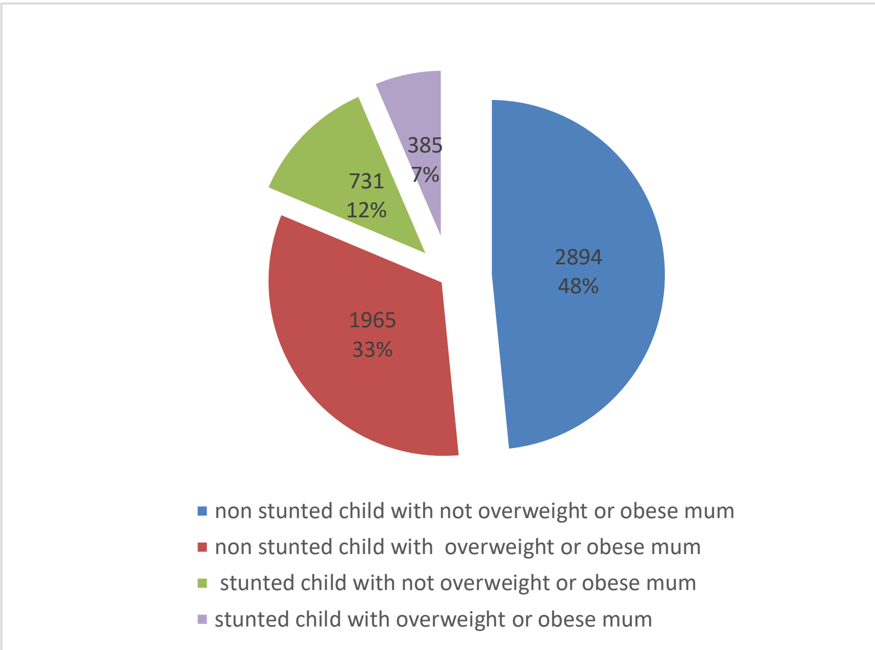
Table 6.1 presents the eight categories classified according to the maternal BMI and child stunting status of the child for the total sample of 5,975.

For the initial analysis, four combinations of child-mother pairs were examined based on the total sample of 5,975. These pairs were categorised as 1) stunted children whose mothers are overweight or obese; (2) stunted children whose mothers are not overweight or obese; (3) non-stunted children with whose mothers are overweight or obese; (4) non-stunted children with whose mothers are not overweight or obese. According to the pie chart (Figure 6.2), nearly half (48.4 per cent) of the child-mother dyads had neither child stunting nor maternal overweight or obesity. Nearly one third (32.8 per cent) of pairs were non-stunted children with an overweight or obese mother. Among the rest of the pairs, 12.2 per cent were a stunted child with no overweight or obese mother, while a combination of stunted child paired with overweight or obese mother was reported as 6.4 per cent.

Table 6.1 Distribution of total sample by child stunting and maternal BMI (*N*=5,975)

	Non stunted		Stunted		Total	
Maternal BMI	**Number**	**percentage**	**Number**	**percentage**	**Number**	**Percentage**
BMI <18.5 (thin)	540	75.8	172	24.1	712	100
BMI 18.5- 24.9 (normal)	2,354	80.8	559	19.1	2,913	100
BMI 25-29.9 (overweight)	1,421	83.1	288	16.8	1,709	100
BMI <30 (obese)	544	84.8	97	15.1	641	100
Total	4,859	81.3	1,116	18.6	5,975	100

Figure 6.2 Distribution of total sample by child stunting status and maternal BMI (N=5,975)

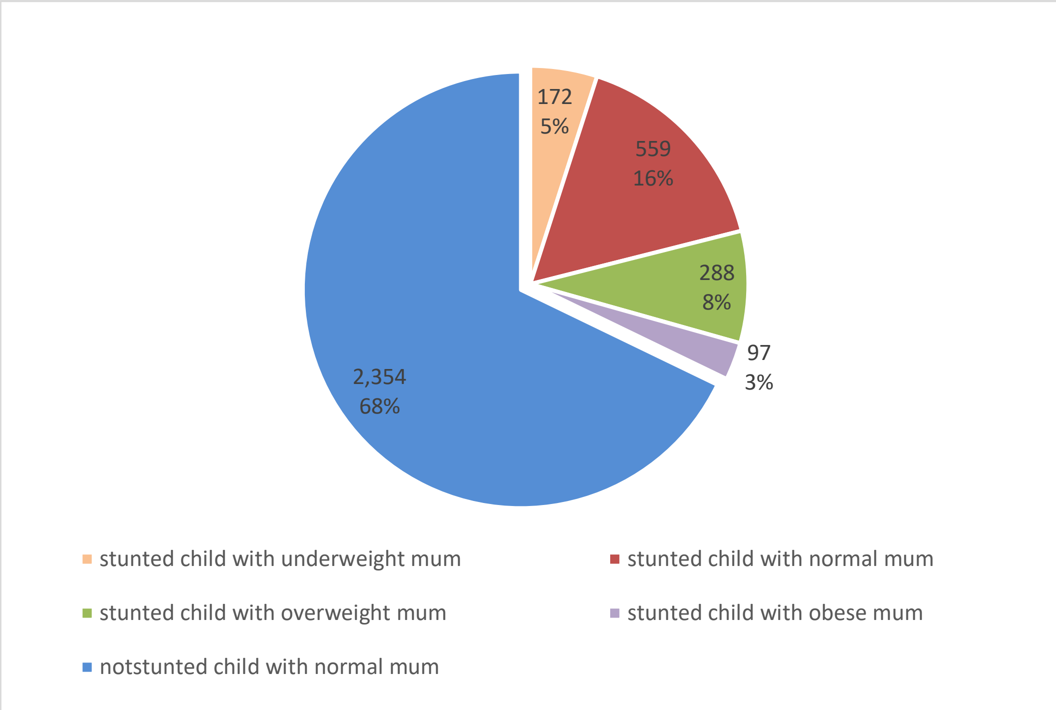


Afterwards, from the sample of 5,975 for the bivariate and multivariate analysis, all stunted children (regardless of maternal BMI) were considered. Pairs are recoded as using the following categories. There was a sample of 3,470 pairs (not considering non-stunted children with overweight, obese or underweight mothers).

i. stunted child (HAZ < −2 SD) and underweight mothers (<18.5 kg/m^2)
ii. stunted child (HAZ < −2 SD) and normal weight mother (18.5 to 24.9 kg/m^2)
iii. stunted child (HAZ < −2 SD) and overweight mother (25 to 29.9 kg/m^2)
iv. stunted child (HAZ < −2 SD) and obese mother (BMI ≤ 30 kg/m^2)
v. non-stunted child (HAZ < −2 SD) and normal weight mothers (18.5 ≤ BMI < 24.9 kg/m2)

Figure 6.3 shows the combination of child-mother pairs based on child stunting for the 3,470 pairs. Among the pairs, more than two thirds (67.8 per cent) were non-stunted child/normal weight mother pairs, while 16.1 per cent were stunted child/normal weight mother pairs. Double burden pairs /SCOWT pairs were reported as 8.3 per cent, while SCOB (stunted child/obese mother) pairs were reported as 2.8 per cent. The remaining pairs were a stunted child with underweight mother, reported as 5.0 per cent.

Figure 6.3 Distribution of total sample by child stunting status and maternal BMI (n = 3,470)



6.7.3 Outcome variable

There is no consistent definition of the DBM at the household level. Therefore to monitor DBM at the household level, different studies suggested measuring undernutrition using multiple anthropometric indices, including weight-for-age *z*-scores (WAZs), height-for-age *z*-scores (HAZs) and weight-for-height Z-scores (WHZ) (Fongar et al., 2019). While each indicator of child undernutrition reflects distinct characteristics of undernutrition, we assessed undernutrition mainly by child stunting in this study.

The rationale for choosing child stunting rather than other anthropometric indicators such as wasting and underweight is that stunting is a sign of chronic malnutrition which is caused by lack of nutrition over a long period leading to a failure of linear growth. In the context of Sri Lanka, undernutrition of children aged under five years remains a chronic development challenge (The World Bank, 2016). Wasting is a symptom of acute transition which results from acute food shortage and illness, whilst underweight is a composite indicator that is influenced by both the height of the child (height-for-age) and his or her weight (weight-for-height), making interpretation complex. Moreover, the factors leading to variation in the prevalence of underweight are similar to those of low height-for-age (de Onis and Blössner, 1997; Garrett and Ruel, 2005).

This study also considered child overweight by looking at the number of children whose weight-for-height *z*-score is more than two (+2.0) standard deviations (SDs) above the median on the World Health Organization (WHO) Child Growth Standards. Only 6.2 per cent (459) of children were reported as overweight from the total sample (7,259) of children aged 6-59 months. Since the child stunting rates are high and constant over the years in the Sri Lankan context, and the objective of this study is to explore the DBM at the household level, this study uses child stunting as an indicator of undernutrition. Stunting was defined using HAZs according to the WHO reference standards, classifying the children as stunted is their HAZ was below minus two standard deviations (-2 SD) from the median of the WHO Child Growth Standards (World Health Organization, 2006). Children who are not stunted were regarded as all other children.

The nutritional status of the mother was calculated using her BMI according to the WHO definition (World Health Organization, 2019a). Being an underweight mother was defined as having a BMI less than 18.5 kg/m^2 while normal weight defined as having a BMI in the range 18.5-24.9 kg/m^2. Maternal overweight is defined as BMI of between 25 and 29.9 kg/m^2 and maternal obesity is defined as having a BMI equal or greater than 30 kg/m^2.

6.7.4 Explanatory variables

Explanatory variables used in the analysis are described in Table 6.2.

Table 6.2 Definition and coding of variables for analyses presented in Chapter 6

Variable	Definition and coding
Child factors	
Child's age in months	Coded as (1) 6,11; (2) 12-24; (3) 25-47; (4) 48-59
Birth weight	Child's birth weight was grouped as (1) <=2.5kg; (0) other
Sex	Coded as (1) male; (2) female
Birth interval	Coded as (1) first birth; (2) less than 24 months; (3) 24-47 months; (4) 48 and more
Child morbidity status	Considered as (1) had at least diarrhoea or cough or fever; (0) had none;
Child immunisation status	Calculated for children aged 12 months & older as (1) fully immunised; (2) partially immunised; (3) none;
Current breastfeeding status	Coded as (1) currently breastfeed; (0) not currently breastfeeding
Breastfeeding duration	Coded as (1) breastfed for less than one year; (2) 2,3 years; (3) over 3 years
Maternal factors (bio-behavioural and social)	
Maternal age (years)	Coded as <=20, 21-29, 30-34, 35 or more years

Variable	Definition and coding
Maternal height	Categorised as (1) short (≤145 cm); (2) average (145.1-155 cm); (3) tall (>155 cm)
Marital status	Grouped into 2 categories: (1) married/cohabiting; (2) widowed/divorced/separated
Educational status	Mother's highest level of completed education. Categorised as (1) up to and including grade 5; (2) grade 6 to O/L (Ordinary level); (3) passed GCE Advanced Level (A/L); (4); Degree and above
Maternal employment status	Coded as (1) currently working outside the household; (2) not working outside the household
Mode of delivery	Coded as (1) Normal; (2) Caesarean
Maternal media exposure	Composite indicator, measuring the extent of exposure to all forms of media (newspaper, radio and TV). Coded as (1) limited; (2) moderate; (3) frequent
Household factors	
Household wealth index	Quintiles of household wealth, Coded as: (1) poorest; (2) poorer; (3) middle; (4) richer; (5) richest
Number of household members	classified as (1) less than five members; (2) 5-7 members; (3); =8 or more members
Maternal ethnicity	Grouped according to the major ethnic groups: (1) Sinhala;(2) Sri Lankan Tamil;(3) Indian Tamils; (4) Muslim, Malay, and Burgher ethnicities
Geographic/Residential factors	
Residential sector	Coded as (1) urban; (2) rural; (3) estate
Geographical province	Nine provinces, corded according to the administrative classification of Sri Lanka

6.7.5 Model building

As discussed in the literature review section and the conceptual framework of the study, DBM and particularly stunted child/overweight or obese mother pairs are driven by multiple overlying factors. Therefore, this study constructed three statistical models that were responsive to the interplay between various covariates. Model 1 included child factors. Model 2 consisted of maternal factors including maternal biological, social and household factors, while Model 3 included all the child, maternal, household and geographical/ residential factors. The rationale behind the modelling approach was to determine the individual effects of each factor on the DBM at the household level, as well as to assess the strength of the relationship between these risk factors and the DBM when all factors are combined. Factors that were significant in the bivariate analysis were included in these models. The present analysis considered a fixed effect multinomial logistic regression models for the multivariate analysis, without considering random intercept. This is due to the low community effect on child nutrition outcomes as reported in the analysis presented in Chapter 5.

6.7.6 Multinomial logistic regression model

The factors associated with mother-child pairs having different forms of malnutrition were modelled using multinomial logistic regression. This study used multinomial logistic regression as the outcome has more than two response categories that are not ordered. The outcome in our analysis has five responses which are: (1) stunted children with underweight mothers, (2) stunted children with normal weight mothers, (3) stunted children with overweight mothers, (4) stunted children with obese mothers, (5) non-stunted children with normal weight mothers.

6.7.7 Data analysis

As an initial analysis, the distribution of the total number of 5,975 mother-child pairs according to the covariates was presented descriptively as percentages. Thereafter, for the subsequent sample of 3,470, bivariate analysis was performed to understand the association between child-mother pairs and child and maternal socioeconomic and residential variables. All variables, which were statistically significantly associated ($p < 0.05$) in bivariate analysis were included in the multinomial logistic regression models. These models were utilized to compare various categories of the DBM with stunted children with the reference group (non-stunted children with normal weight mothers).

For the multinomial logistic regression models, we estimated relative risk ratios (RRRs) and confidence intervals (CIs) for being a stunted child with an underweight mother, a stunted child with a normal weight mother, a stunted child with an overweight mother, and a stunted child with an obese mother compared with being a non-stunted child with a normal weight mother (the baseline pair). The values indicate the effect on the risk of being in the outcome category relative to the reference category, based on the results of the regression analysis. A parameter was considered statistically significant if the p-value was less than 0.05.

The association between consumption of a variety of foods and the child-mother pairs was also assessed. The main food patterns were explored by undertaking a principal component analysis (PCA) of the different foods that a child and mother could have or have not consumed. Data were based on mother's recall of mothers/child's consumption of food groups, 24-hour preceding the DHS interview of the mother. The results of the PCA analysis were used to develop a composite "food diversity score ". This score subsequently recoded the cumulative percentage into four quintiles, equally distributed by 25 per cent for each quintile.

6.8 Results of the descriptive analysis

6.8.1 Maternal and child nutritional status

The mean BMI of the mothers was reported as 24.05 kg/m^2 (Appendix K). Among them, 11.9 per cent were underweight (BMI < 18.5), 48.7 per cent were normal weight (BMI 18.5-24.9), 28.6 per cent overweight (BMI 25-29.9) and 11.0 per cent obese (BMI >= 30). The relationship between maternal BMI categories and socioeconomic characteristics was analysed and the results are shown in Table 6.3. According to the results, child characteristics such as age, birth interval, birth weight and current breastfeeding status were significantly associated with maternal BMI. Thin mothers are likely to have low birth weight children (18.4 per cent), while the mothers of normal weight babies are more likely to be overweight and obese (29.6 per cent and 11.2 per cent) at the time of the survey. Mothers who are not currently breastfeeding were more likely than breastfeeding mothers to be overweight (30.1 per cent) or obese (13.2 per cent).

Maternal background characteristics were significantly associated with maternal BMI, except for maternal employment status. Mothers are more likely to be overweight or obese when the age increases (the 35 years and over age group had the highest overweight percentage of 33.5 per cent and the highest obese percentage of 13.8 per cent). Of the 34 women who had completed a degree and above level education, 37.5 per cent were overweight and a further 10.6 per cent were obese. In addition, BMI status is associated with household wealth, as thin mothers (17.5 per cent) and normal (52.5 per cent) are highly represented in the lowest wealth group. In contrast, half of the richest wealth group were either overweight (34.2 per cent) or obese (16.2 per cent). The residential sector is associated with maternal BMI level, as urban mothers are likely to be overweight (33.1 per cent) and obese (16.3 per cent), while about a quarter of the (23.5 per cent) mothers in the estate sector are thin. Further, by ethnicity, a higher proportion of Muslim mothers are reported as overweight or obese (36.7 per cent and 17.8 per cent respectively) than is the case for other ethnic groups. In contrast, being underweight is most common among Indian Tamil mothers (21.2 per cent). Also, overweight (31.7 per cent) and obese mothers (14 per cent) are most common in the western Province, while thin mothers are mostly found in the Southern Province (15.9 per cent).

Table 6.3 Association between child, maternal, household and residential factors and maternal body mass index (BMI) (*N*=5,975)

Variables	Thin (BMI< 18.5) n=712	Normal (BMI 18.5-24.9) n=2,913	Overweight (BMI 25.0-29.9) n=1,709	Obese (BMI >= 30) n=641	N 5975	P-value
Child age in months						
6-11 months	10.9	49.7	27.3	11.9	713	0.000
12-47 months	12.7	48.8	28.1	10.1	4,140	
48-59 months	9.5	47.5	3.09	11.9	1,122	
Birth interval						0.000
First birth	16.4	49.8	25.8	7.7	2,119	
<24	8.3	47.8	27.4	16.3	324	
24-47	10.6	48.7	28.7	11.8	1,257	
48 and more	8.8	47.8	31.2	12	2,275	
Sex						
Male	11.4	49.9	28.3	10.3	3,068	0.211
Female	12.4	47.4	28.9	11.1	2,907	
Birth weight status					n=5812	
Normal weight	10.5	48.5	29.6	11.2	4,825	0.000
Low birth weight	18.4	50.2	23.5	7.8	987	
Current breastfeeding					n=5919	
Yes	13.1	50.0	27.5	9.2	3,686	0.000
No	10.0	46.4	30.1	13.2	2,233	
Child morbidity					n=5967	
Not had all	11.9	49.0	27.8	11.2	4,408	0.056
Had one of the diseases	11.8	48.1	30.7	9.3	1,559	

Variables	Thin (BMI< 18.5) n=712	Normal (BMI 18.5-24.9) n=2,913	Overweight (BMI 25.0-29.9) n=1,709	Obese (BMI >= 30) n=641	N 5975	P-value
Maternal age						
<=20	25.7	52.0	17.3	4.8	225	0.000
21-29	15.1	49.3	26.2	9.1	2,874	
30-34	7.9	49.2	30.7	12.0	1,781	
35+	6.9	45.6	33.5	13.8	1,095	
Marital status						
Currently married/living together	11.9	49.0	28.7	11.0	5,865	0.280
Widowed/divorced/separated	11.8	57.2	21.8	9.0	110	
Maternal education						
Up to grade 5	17.9	49.6	20.9	11.4	306	0.000
Grade 6 to Ordinary Level	12.6	49.1	27.8	10.3	4,006	
Advanced Level	9.6	48.2	30.4	11.6	1,345	
Degree and above	6.2	45.6	37.4	10.6	34	
Maternal Employment status						
Employed	11.9	49.9	27.7	10.2	1,395	0.719
Not employed	11.8	48.3	28.8	10.8	4,580	
Wealth index						
Lowest	17.5	52.5	22.6	7.2	1,504	0.000
Second	15.0	49.0	26.8	9.0	1,216	
Middle	10.9	47.5	3.0	11.4	1,138	
Fourth	8.0	48.1	31.9	11.7	1,154	
Highest	4.9	44.6	34.2	16.2	963	

Variables	Thin (BMI< 18.5) n=712	Normal (BMI 18.5-24.9) n=2,913	Overweight (BMI 25.0-29.9) n=1,709	Obese (BMI >= 30) n=641	N 5975	P-value
Residential sector						
Urban	8.5	41.9	33.1	16.3	949	0.000
Rural	11.7	49.7	28.5	10	4,665	
Estate	23.5	54.0	17.7	4.7	361	
Ethnicity						
Sinhala	11.9	49.9	28.6	9.7	3,946	0.000
Sri Lankan Tamil	12.3	49.6	26.6	11.0	1,211	
Indian Tamil	21.2	55.4	18.4	4.8	184	
Muslims Burgher and Malay	8.3	37.0	36.7	17.8	634	
Province						
Western	8.7	45.5	31.7	14.0	1,150	0.000
Central	12.3	52.2	26.7	8.6	751	
Southern	15.9	51.0	24.7	8.3	696	
Northern	10.1	48.3	29.5	11.9	713	
Eastern	9.9	47.7	29.9	12.3	664	
North-Western	12.3	46.3	30.5	10.8	665	
North-Central	12.4	48.7	26.6	12.1	402	
Uva	11.5	54.6	26.7	7.1	408	
Sabaragamuwa	17.3	48.1	27.0	7.6	526	

P < 0.05 **P<0.01**P<0.001

For the children, mean HAZ was -1.01 (SD 1.20 and median was reported as -1.03) (Appendix L). There were 18.7 per cent (n = 1,116) who were stunted while 81.3 per cent of children were not stunted (4,859). The mean age of the children was 31 months.

6.8.2 Relationship between mother-child pairs and background characteristics

Table 6.4 presents the relationship between mother-child pairs and background characteristics. The association was explored using cross-tabulations and a chi-square p-value is given showing whether the association is statistically significant or not. Among child factors, child's age, birth interval and birth weight have a significant association with the nutritional status of child-mother pairs. For example, the SCOWT (Stunted child-overweight mother) pairs vary from 10.1 per cent among children aged 6-11 months to 5.8 per cent among children aged 48-59 months. Stunted child/normal weight mother pair was more likely to be represented among low birth weight babies (27.4 per cent) than among normal birth weight babies.

Child's sex, child morbidity, the child's breastfeeding status and the child's vaccination status were not significantly associated with the child-mother pairs. However, maternal factors did exhibit significant associations. For instance, paradoxical child-mother pairs (stunted children with overweight or obese mothers) were more likely among mothers aged 35 and over than among younger mothers. Also, maternal height was significantly associated with the DBM, as short mothers were more likely to belong to the SCOWT and SCOB pairs (13.7 per cent and 6.5 per cent respectively). Also, normal weight mother-child pairs constitute a higher proportion of all mother-child pairs in the richest households (76.2 per cent). The richest households also had the lowest proportion of stunted children with underweight mother pair (1.2 per cent) and mothers who belong to the stunted-overweight pair were more likely to be unemployed (8.9 per cent).

Maternal education status was significantly associated with the nutritional status of mother-child pairs, as all pairs were more likely to belong to the grade 6 to O/L Ordinary level category. Stunted child dyads with underweight and normal weight mothers are significantly more common among Indian Tamils than among other groups (14.8 and 30.7 per cent). In contrast, DBM pairs are relatively most common among Muslims and other minorities including Malays and Burghers (14.0 per cent are SCOWT pairs and 6.8 per cent are SCOB pairs). Among the other maternal factors, mode of delivery was significantly associated with the nutritional status of child-mother pairs as SCOWT pairs and SCOB pairs were more often spotted among children who had a Caesarean delivery (9.7 per cent and 4.9 per cent).

Stunted child/overweight mother and stunted child/obese mother pairs lived in households with 8 and more members (10.7 and 5.5 per cent). These paradoxical pairs are more common in urban areas (8.9 per cent and 4.3 per cent), whereas stunted child/underweight mothers were most common in the estate sector (13.7 per cent). SCOWT pairs are settled in the Central Province (10.0 per cent). The highest proportion of SCOB pairs lived in the Eastern Province (where the majority belong to the Muslim religion) has 3.9 per cent. Other covariates, such as child's vaccination status, child's morbidity status, and maternal media exposure and other household environment and sanitation covariates such as the source of cooking, water supply and availability of livestock were not significantly associated with the nutritional status of mother-child pairs (results not shown separately in Table 6.4).

Table 6.4 Percentage of child-mother pairs by demographic and socioeconomic characteristics with Chi-square tests of association (n=3,470)

Covariates	**Stunted child/under-weight mother**	**Stunted child/ normal weight mother**	**Stunted child/over-weight mother**	**Stunted child/ obese mother**	**Non-stunted child/normal weight mother**	***n***	***p*-value**
Total number	**172**	**559**	**288**	**97**	**2,354**		
Overall percentage	**4.9**	**16.1**	**8.3**	**2.8**	**67.8**		
Age in months							
6-11 months	2.6	15.4	10.1	1.4	70.2	414	0.000
12-47 months	5.8	17.1	8.6	3.0	65.3	2,454	
48-59 months	2.8	12.4	5.8	2.6	76.2	602	
Birth interval							
First birth	6.5	13.9	6.4	2.0	71.0	1,244	0.000
< 24 months	4.1	18.1	10.3	5.1	62.1	193	
24-47 months	4.3	16.6	9.7	3.1	66.2	740	
48 months or more	3.8	17.6	8.9	3.0	66.5	1,293	
Sex							
Male	4.6	17.5	8.3	2.5	66.9	1,815	0.118
Female	5.3	14.5	8.2	3.0	68.8	1,655	

Covariates	**Stunted child/under-weight mother**	**Stunted child/ normal weight mother**	**Stunted child/over-weight mother**	**Stunted child/ obese mother**	**Non-stunted child/normal weight mother**	***n***	***p*-value**
Birth weight status						n=3,382	
Normal weight	3.4	13.3	7.8	2.7	72.5	2,725	0.000
Low birth weight	11.2	27.4	10.2	3.0	48.1	657	
Child morbidity						n=3,213	
Not had all	5.1	46.6	8.5	2.8	66.7	2,589	0.224
Had one of the diseases	4.4	14.3	7.5	2.6	71.0	624	
Breastfeeding status						n=3,433	
Still breastfeeding	5.3	17.2	8.8	2.4	66.1	2,211	0.061
Not breastfeeding	4.3	13.9	7.2	3.5	70.9	1,222	
Vaccination status							
Did not receive any	5.1	18.2	8.7	3.6	64.2	274	0.305
Partial	4.7	14.9	7.9	2.6	69.7	2.050	
Full	5.3	17.7	8.7	2.9	65.2	1,139	
Maternal age							
<=20 years	10.4	11.8	5.5	2.1	69.9	143	0.000
21-29 years	6.4	16.3	7.6	2.2	67.2	1,696	
30-34 years	2.8	15.9	8.3	3.2	69.6	1,025	
35 years or more	3.1	16.6	10.5	3.8	65.8	606	

Covariates	Stunted child/under-weight mother	Stunted child/ normal weight mother	Stunted child/over-weight mother	Stunted child/ obese mother	Non-stunted child/normal weight mother	*n*	*p*-value
Maternal height							
Short <=145 cm	7.5	33.2	13.7	6.5	38.9	277	0.000
Average 145.1-155 cm	5.8	18.2	9.8	2.8	63.1	1,992	
Tall 155.1 & over	2.7	8.5	4.5	1.8	82.3	1,201	
Maternal education							
Up to grade 5	10.4	27.2	7.3	2.6	52.3	191	0.000
Grade 6 to Ordinary Level	5.4	16.8	8.7	3.0	65.9	2,376	
Advanced Level	2.7	11.5	7.1	2.1	76.4	738	
Degree and above	1.8	13.3	7.8	2.4	74.5	165	
Maternal marital status							
Currently married/living together	4.8	15.9	8.4	2.7	67.9	3,398	
Widowed/separated/divorced	8.3	25.0	0.0	4.1	62.5	72	0.054
Maternal Employment status							
Employed	5.8	17.5	6.2	2.7	68.3	811	0.000
Not employed	4.8	15.6	8.9	2.8	67.6	2,659	
Ethnicity							

Covariates	**Stunted child/under-weight mother**	**Stunted child/ normal weight mother**	**Stunted child/over-weight mother**	**Stunted child/ obese mother**	**Non-stunted child/normal weight mother**	***n***	***p*-value**
Sinhalese	4.4	14.6	7.4	2.3	71.1	2,298	0.000
Sri Lankan Tamil	5.7	17.5	8.4	2.8	65.3	730	
Indian Tamil	14.8	30.7	8.1	1.4	45.1	135	
Muslims and others	2.6	17.2	14.0	6.8	59.2	307	
Type of delivery						n=3451	
Normal	5.3	15.8	7.7	2.0	69.0	2,495	0.000
Caesarean	3.8	16.9	9.7	4.9	64.5	956	
Household factors							
Household size							
< 5 members	5.0	14.3	8.7	1.9	69.8	1,454	0.000
5-7 members	4.7	17.3	7.7	3.1	67.1	1,780	
8 and more	5.9	17.8	10.7	5.5	60.5	236	
Wealth index							
Lowest	8.8	20.0	9.1	1.7	60.2	984	0.000
Second	5.2	17.0	8.4	3.4	65.6	720	
Middle	4.2	15.5	7.1	2.7	70.3	630	
Fourth	2.2	14.4	7.0	3.3	72.9	636	
Highest	1.2	9.8	9.4	3.4	76.2	500	

Covariates	Stunted child/under-weight mother	Stunted child/ normal weight mother	Stunted child/over-weight mother	Stunted child/ obese mother	Non-stunted child/normal weight mother	*n*	*p*-value
Residential factors							
Residential sector							
Urban	3.5	12.1	8.9	4.3	70.9	479	0.000
Rural	4.3	15.8	8.1	2.6	68.9	2,737	
Estate	13.7	26.7	8.2	1.1	50.0	254	
Province						n= 3470	
Western	3.0	13.5	8.7	3.7	70.9	620	0.000
Central	7.5	23.3	10.0	2.0	56.9	488	
Southern	5.9	12.8	4.4	2.2	74.6	406	
Northern	3.9	7.4	7.6	3.4	67.4	406	
Eastern	3.1	16.4	9.9	3.9	66.4	382	
North-Western	6.2	12.4	8.6	1.8	70.8	370	
North-Central	3.4	11.9	9.4	3.4	71.9	234	
Uva	5.0	18.5	6.9	1.9	67.5	259	
Sabaragamuwa	6.5	17.3	8.5	1.9	65.5	305	

P < 0.05 **P<0.01**P<0.001

6.9 Results of the adjusted multinomial regression analysis

This section is divided into four subsections which present the results from the multinomial logistic regression comparing each of the other outcome categories, with the base (reference) category of non-stunted child/normal weight pairs, using the same models for each comparison. The results are reported as relative risk ratios with 95 per cent confidence interval (CIs).

6.9.1 Households with paradoxical pairs of stunted children and overweight mothers (SCOWT)

The multinomial regression results show the influence of various predictors on the prevalence of the DBM, or paradoxical pairs and other pairs, compared to the reference group (Table 6.5). Model 1, including only child factors, revealed that child's age and low birth weight (LBW) status were significant predictors of the DBM for households with stunted children and overweight mothers (SCOWT). These pairs were significantly less likely for children aged between 48-59 months, relative to the children who were aged 6-11 months (RRR: 0.52, 95 per cent CI [0.32, 0.85]). LBW children had double the risk of being in SCOWT child-mother pairs relative to normal birth weight children. The risk would be expected to increase by a factor of 2.07 given the other variables in the model are held constant (RRR: 2.07, 95 per cent CI [1.53, 2.80]). In Model 1, birth interval was not associated with the SCOWT pairs.

Model 2 included only maternal and household factors. Maternal age, maternal stature, ethnicity and wealth index are found to be significant in this model. Mothers aged 35 years or more had a higher risk of being in SCOWT pairs, relative to the mothers aged less than 20 years, for instance, the relative risk of having these pairs relative to the normal pairs is increased by a factor of 2.11 (RRR: 2.11, 95 per cent CI [0.95, 4.66). Maternal stature was also important, as the risk is greatly increased for the mothers with short stature compared to normal height (RRR= 2.21, 95 per cent CI [1.47, 3.22]). Maternal employment status has some tendency towards significance (p = 0.06) as the relative risk of being a SCOWT pair is increased by a factor of 1.40 for employed mothers compared to unemployed mothers (RRR: 1.40, 95 per cent CI [0.98, 1.99]). Mothers belonging to the Muslims and other minorities (Burgher and Malay) were 2.48 times more likely to be in SCOWT pairs compared with Sinhalese mothers. Some factors, such as the number of household members, delivery method, and maternal education were found to be not significantly associated with the DBM, hence they were removed from Model 3. In Model 3, child, maternal, household and residential factors are controlled, and all child and maternal factors that were statistically significant in Models 1 and 2 remained significant. The largest single effect is for mothers belonging to the Muslim, Malay and Burgher ethnicity. The residential sector was not significantly associated with the risk of being in a SCOWT pair. The risk of a SCOWT pair is less likely to be seen in the Southern Province when compared to the Western Province (RRR: 0.49, 95 per cent CI [0.27, 0.88]).

Table 6.5 Adjusted risk ratios (95%CI) of factors associated with the risk of being in a stunted child/overweight mother (SCOWT) pairs

Covariate and category	Model 1	Model 2	Model 3
	Estimates (CI)	Estimates (CI)	Estimates (CI)
Intercept	0.90 (0.06,0.13)	0.59 (0.02,0.16)	0.084 (0.02,0.26)
Age in months			
6-11 months	1.00		1.00
12-47 months	0.92 (0.64,1.33)		0.92 (0.63,1.35)
48-59 months	0.52 (0.32,0.85) **		0.49(0.30,0.83) **
Birth interval			
First birth	1.00		
< 24 months	1.91 (0.82,4.43)		
24-47 months	1.72 (0.82,3.62)		
48 months or more	1.64 (0.79,3.39)		
Birth weight status			
Normal birth weight	1.00		1.00
Low birth weight	2.07 (1.53,2.80) ***		1.81 (1.32,2.47) ***
Maternal factors			
Maternal age			
<= 20 years		1.00	1.00
21-29 years		1.54 (0.72,3.29)	1.59 (0.74,3.43)
30-34 years		1.72 (0.79,3.74)	1.92 (0.87,4.20)
35 years or more		2.11 (0.95,4.66) *	2.32(1.05,5.15) *
Maternal height			
Short <=145 cm		2.21 (1.47,3.32) ***	2.12 (1.40,3.22) ***
Average 145.1-155 cm		1.00	1.00
Tall 155.1 & over		0.35 (0.25,0.48) ***	0.36 (0.26,0.50) ***
Maternal education			
Up to grade 5		1.00	
Grade 6 to Ordinary Level		1.20 (0.65,2.21)	
Advanced Level		0.92 (0.46,1.82)	
Degree and above		1.20 (0.39,2.32)	

Covariate and category	Model 1	Model 2	Model 3
	Estimates (CI)	Estimates (CI)	Estimates (CI)
Maternal Employment status			
Employed		1.00	
Not employed		1.40 (0.98,1.99)	
Delivery method			
Normal		1.00	
Caesarean		1.26 (0.95,1.67)	
Household factors			
Ethnicity			
Sinhalese		1.00	1.00
Sri Lankan Tamil		1.21 (0.85,1.73)	1.38 (0.82,2.34)
Indian Tamil		1.37 (0.66,2.83)	1.21 (0.47,3.15)
Muslims and others		2.48 (1.69,3.64) ***	2.46 (1.60,3.77) ***
Household size			
< 5 members		1.00	
5-7 members		0.90 (0.69,1.17)	
8 members and more		1.14 (0.70,1.88)	
Wealth index			
Lowest		1.00	1.00
Second		0.87 (0.58,1.23)	0.78 (0.53,1.15)
Middle		0.74 (0.45,1.03)	0.66 (0.43,1.03)
Fourth		0.68 (0.41,0.97) *	0.61 (0.39,0.97) *
Highest		1.12 (0.56,1.43)	1.03 (0.62.1.71)
Residential factors			
Residential sector			
Urban			1.00
Rural			0.94 (0.63,1.41)
Estate			0.64 (0.28,1.46)
Province			
Western			1.00
Central			1.32 (0.83,2.10)
Southern			0.49 (0.27,0.88) *
Northern			0.66 (0.33,1.31)
Eastern			0.89 (0.52,1.53)
North-Western			0.99 (0.60,1.63)
North-Central			1.03 (0.58,1.81)
Uva			0.74 (0.41,1.35)

Covariate and category	Model 1	Model 2	Model 3
	Estimates (CI)	Estimates (CI)	Estimates (CI)
Sabaragamuwa			6.82 (0.47, 1.44)

P < 0.05 **P<0.01**P<0.001

6.9.2 Households with paradoxical pairs of stunted children and obese mothers (SCOB)

When identifying the factors associated with adiposity among mothers with a stunted child in the same household in cases where the mothers were obese (SCOB pairs), the results were similar to the previous model with few exceptions. For instance, in Model 1, only the birth weight status was statistically significant, where low birth weight increased the risk of being in a SCOB pair (RRR: 1.80, 95 per cent CI [1.08, 3.01]) (Table 6.6).

In Model 2, including maternal and household factors, short mothers have an increased relative risk of being obese and paired with a stunted child (RRR: 3.49, 95 per cent CI [1.94, 6.27]). The relative risk related to the delivery method is increased significantly compared to the previous SCOWT model, as it increased risk by 2.65 times that of a normal delivery (RRR: 2.65, 95 per cent CI [1.72, 4.10]). Unlike in the SCOWT model, household size is significantly associated, as the risk of having the DBM is increased for households with more than eight members (RRR: 2.89, 95 per cent CI [1.42, 5.89]). In addition, mothers belonging to Muslim and other minority groups are much more likely to be obese and part of a SCOB pair with a stunted child (RRR: 4.07, 95 per cent CI [2.33, 7.11]) while other factors are held constant. The risk for Muslim women is 4.07 times that of Sinhalese mothers. Maternal age, education and employment status are not significantly associated with the risk of being in a SCOB pair and are therefore not included in the final model.

In Model 3, after controlling for child, maternal. Household and residential factors, none of the residential factors (sector or province) was found significant, while other factors remained significant similar to Model 2. However, some of the effects are decreased. For example, the risk associated with SCOB pairs is reduced for Muslim mothers, when all other factors are controlled (RRR: 3.26, 95 per cent CI: [1.68, 6.30]) compared to Model 2. Also, the magnitude of the Caesarean delivery variable is reduced in Model 3 compared with Model 2, but statistically significant when controlling for the residential factors.

Table 6.6 Adjusted risk ratios (95%CI) of factors associated with the risk of being in a stunted child/obese mother (SCOB) pairs

Covariate and category	Model 1 Estimates (CI)	Model 2 Estimates (CI)	Model 3 Estimates (CI)
Intercept	0.012 (0.00,0.03)	0.009 (0.00,0.47)	0.017 (0.004,0.64)
Child factors			
Age in months			
6-11 months	1.00		
12-47 months	2.13 (0.91,4.97)		
48-59 months	1.60 (0.61,4.16)		
Birth interval			
First birth	1.00		
< 24 months	1.94 (0.53,7.11)		
24-47 months	1.10 (0.32,3.57)		
48 months or more	1.01 (0.30,3.34)		
Birth weight status			
Normal	1.00		1.00
Low birth weight	1.80 (1.08,3.01) *		1.52 (0.89,2.58) *
Maternal factors			
Maternal age			
<= 20 years		1.00	
21-29 years		1.01 (0.30,3.43)	
30-34 years		1.33 (0.40,4.83)	
35 years or more		1.41 (0.45,5.57)	
Maternal height			
Short <=145 cm		3.49 (1.94,6.27) ***	3.51 (1.93,6.40) ***
Average 145.1-155 cm		1.00	1.00
Tall 155.1 & over		0.50 (0.30,0.83) ***	0.47 (0.28,0.80) **
Maternal education			
Up to grade 5		1.00	
Grade 6 to Ordinary Level		1.00 (0.37,2.27)	
Advanced Level		0.50 (0.16,1.55)	
Degree and above		0.50 (0.11,2.17)	
Maternal employment status			
Employed		1.00	
Not employed		0.95 (0.55,1.63)	
Delivery method			

Covariate and category	Model 1 Estimates (CI)	Model 2 Estimates (CI)	Model 3 Estimates (CI)
Normal		1.00	1.00
Caesarean		2.65 (1.72,4.10) ***	2.43 (1.56,3.79) ***
Household factors			
Ethnicity			
Sinhalese		1.00	1.00
Sri Lankan Tamil		1.88 (1.05,3.36)	1.32 (0.56,3.10)
Indian Tamil		1.13 (0.25,5.06)	1.58 (0.22,10.9)
Muslims and others		4.07 (2.33,7.11) ***	3.26 (1.68,6.30) ***
Household size			
< 5 members		1.00	1.00
5-7 members		1.69 (1.05,2.71) *	1.67 (1.02,2.67) *
8 members and more		2.89 (1.42,5.89) **	3.28 (1.59,6.78) **
Wealth index			
Lowest		1.00	1.00
Second		2.00 (1.04,3.96) *	2.09 (1.03,4.11) *
Middle		1.77 (0.83,3.75)	1.66 (0.75,3.70)
Fourth		1.87 (0.89,3.93)	1.80 (0.81,3.99)
Highest		2.36 (1.03,5.43)	2.05 (0.82,5.14)
Residential factors			
Residential sector			
Urban			1.00
Rural			0.84 (0.52,1.71)
Estate			0.52 (0.96,2.99)
Province			
Western			1.00
Central			0.73 (0.32,1.66)
Southern			0.60 (0.24,1.31)
Northern			1.47 (0.44,3.44)
Eastern			0.95 (0.39,1.97)
North-Western			0.50 (0.18,1.25)
North-Central			1.05 (0.41,2.38)
Uva			0.58 (0.21,1.66)
Sabaragamuwa			0.63 (0.25,1.75)

P < 0.05 **P<0.01**P<0.001

6.9.3 Households with stunted child/underweight mother pairs (SCUWT)

This section considers households with stunted child/underweight mother pairs, comparing them to normal pairs (non-stunted child/normal weight mother). According to the results in Table 6.7, child's age and low birth weight are statistically significant in Model 1. For instance, low birth weight status increased the risk of being in a stunted child/underweight mother pair by almost five times compared with a normal birth weight (RRR: 4.98, 95 per cent CI [3.58, 6.94]). Birth interval was not associated with the mother-child nutritional status in Model 1.

In Model 2, maternal age, maternal stature, educational level, wealth status and ethnicity were found statistically significant with these pairs. The maternal age predictor in Model 2 indicated that a mother's risk of being in a stunted child/underweight mother pairs was 63 per cent lower when mothers were between the ages of 30-34 years ($p < 0.001$), when compared to mothers below the age of 20 years. Unlike with DBM pairs, maternal education has a marginally significant effect on stunted child/underweight mother pairs at the household level (RRR: 0.49, 95 per cent CI [0.23, 1.02]).

Households belonging to the Indian Tamil ethnicity have an increased risk (RRR: 2.09, 95 per cent CI [1.14, 3.85]), of having stunted child-underweight mother pairs; and households in the upper wealth quintiles are at a decreased risk of having such pairs (for the highest wealth group the risk has reduced to 18 per cent of its value among the poorest quintile (RRR: 0.18, 95 per cent CI [0.07, 0.49]). Mode of delivery, employment status and the household size were not significant in Model 2 and were removed from Model 3.

In Model 3, adjusting for all factors which were significant in the previous models, child's age, birth weight status, maternal age, maternal stature and wealth status were found significant predictors for the stunted child/underweight mother pairs. None of the residential factors was significant.

In short, analysis of maternal, socioeconomic and residential factors seems to indicate that children in the age group 12-47 months, with low birth weight, born to younger women in poorer households, are more likely to be in stunted child/underweight mother pairs.

Table 6.7 Adjusted risk ratios (95%CI) of factors associated with the risk of being in a stunted child/underweight mother pair

Covariate and category	Model 1 Estimates (CI)	Model 2 Estimates (CI)	Model 3 Estimates (CI)
Intercept	0.028 (0.01,0.54)	0.50 (0.21,1.20)	0.10 (0.29,0.37)
Child factors			
Age in months			
6-11 months	1.00		1.00
12-47 months	2.54 (1.37,4.79) **		2.79 (1.27,4.63) **
48-59 months	0.98 (0.44,2.17)		1.00 (0.43,2.31)
Birth interval			
First birth	1.00		
< 24 months	0.94 (0.21,2.38)		
24-47 months	0.92 (0.38,2.27)		
48 months or more	0.75 (0.32,1.73)		
Birth weight status			
Normal	1.00		1.00
Low birth weight	4.98 (3.58,6.94) ***		3.83 (2.70,5.43) ***
Maternal age			
<= 20 years		1.00	1.00
21-29 years		0.79 (0.44,1.44)	0.99 (0.51,1.88)
30-34 years		0.37 (0.19,0.75) **	0.46 (0.22,0.97) *
35 years or more		0.33 (0.15,0.72) *	0.39 (0.18,0.87) *
Maternal height			
Short <=145 cm		1.91(1.13,3.22) *	1.99 (1.16,3.14) *
Average 145.1-155 cm		1.00	1.00
Tall 155.1 & over		0.41 (0.27,0.61) ***	0.45 (0.30,0.69) ***
Maternal education			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		0.60 (0.34,1.06)	0.76 (0.41,1.39)
Advanced Level		0.49 (0.23,1.02) *	0.67 (0.31,1.46)
Degree and above		0.47 (0.12,1.80)	0.65 (0.15,2.52)
Maternal employment status			
Employed		1.00	
Not employed		0.79 (0.56,1.51)	

Covariate and category	Model 1 Estimates (CI)	Model 2 Estimates (CI)	Model 3 Estimates (CI)
Delivery method			
Normal		1.00	
Caesarean		1.01 (0.68,1.18)	
Household factors			
Ethnicity			
Sinhalese		1.00	1.00
Sri Lankan Tamil		0.76 (0.49,1.16)	1.28 (0.64,2.57)
Indian Tamil		2.09 (1.14,3.85) *	1.86 (0.77,4.48)
Muslims and others		0.65 (0.30,1.38)	0.94 (0.42,2.09)
Household size		1.00	
< 5 members		1.02 (0.73,1.44)	
5-7 members		1.44 (0.77,2.69)	
8 members and more			
Wealth index			
Lowest		1.00	1.00
Second		0.63 (0.41,0.98) *	0.62 (0.39,0.98) *
Middle		0.52 (0.29,0.79) **	0.49 (0.27,0.78) **
Fourth		0.26 (0.13,0,48) ***	0.25 (0.13,0.48) ***
Highest		0.18 (0.07,0.46) ***	0.18 (0.07,0.49) ***
Residential factors			
Residential sector			
Urban			1.00
Rural			0.65 (0.39,1.29)
Estate			0.72 (0.31,1.93)
Province			
Western			1.00
Central			1.38 (0.71,2.74)
Southern			1.68 (0.82,3.09)
Northern			0.59 (0.22,1.45)
Eastern			0.57 (0.22,1.31)
North-Western			1.72 (0.80,3.12)
North-Central			0.93 (0.35,2.12)
Uva			0.74 (0.32,1.69)
Sabaragamuwa			1.14 (0.57,2.41)

P < 0.05 **P<0.01**P<0.001

6.9.4 Households with stunted children/normal weight mothers (SCNWT)

When looking at the last outcome: households with stunted children/normal weight mother pairs, various child, and maternal socioeconomic and residential explanatory factors help to predict the likelihood of households with normal weight mothers to be paired with stunted children (Table 6.8). In Model 1, low birth weight was the only significant variable, for instance, low birth weight increases the risk of a child being in a stunted child/normal weight mother pair by more than three times (RRR: 3.23, 95 per cent CI [2.60, 4.02]).

Regarding the predictors grouped under maternal and household factors (Model 2), maternal stature being short (RRR: 2.72, 95 per cent CI [2.00, 3.71]) and maternal age being 21-29 years (RRR: 1.62, 95 per cent CI: [0.92, 2.78]) were found to be associated with a higher risk for stunted child/normal weight mother household pairs. In addition, normal weight mothers who completed A-level were 47 per cent less likely to have stunted infants (RRR: 0.53, 95 per cent CI [0.33, 0.70]), compared to mothers who have completed only primary education. Moreover, mothers whose ethnicity was Indian Tamil had an increased risk of 1.94 times (95 per cent CI [1.23, 3.08]) of being in a stunted child/normal weight mother pair. Household size and wealth also demonstrated as significant predictors, as the higher the household wealth, lower the likelihood of having a stunted child paired with a normal weight mother. For instance, being in the richest household quintile reduced risk, compared to the other lower wealth groups (RRR: 0.57, 95 per cent CI [0.37, 0.86]). Maternal employment status and mode of delivery were not found to have any significant relationship with stunted child/normal weight mother pair.

In Model 3, where all the significant predictors were included together with residential factors, household wealth was no longer statistically significant, while the effect of the maternal age is increased and significantly associated with the risk of being a stunted child paired with a normal weight mother at all ages over 20 years. Indian Tamil ethnicity was no longer significant in this model, however, Muslim ethnicity remained significant.

Considering the residential factors, sector has not shown any association with the chance of being in a stunted child/normal weight mother pair ($p > 0.05$). Nevertheless, the risk of childhood stunting within households with normal weight mothers was 46 per cent higher for Central Province compared to Western Province (RRR: 1.46, 95 per cent CI: [1.01, 2.12]).

Table 6.8 Adjusted risk ratios (95% CI) of factors associated with the risk of being in a stunted child/normal weight mother pair

Covariate and category	Model 1 Estimates (CI)	Model 2 Estimates (CI)	Model 3 Estimates (CI)
Intercept	0.13 (0.09,0.18)	0.27 (0.14,0.55)	0.14 (0.66,0.32)
Child factors			
Age in months			
6-11 months	1.00		
12-47 months	1.18 (0.27,0.87)		
48-59 months	0.73 (0.10,0.50)		
Birth interval			
First birth	1.00		
< 24 months	1.55 (0.17,0.82)		
24-47 months	1.38 (0.24,0.79)		
48 months or more	1.40 (0.22,0.81)		
Birth weight status			
Normal	1.00		1.00
Low birth weight	3.23 (2.60,4.02) ***		2.60 (2.07,3.27) ***
Maternal Age			
<= 20 years		1.00	1.00
21-29 years		1.62 (0.95,2.78) *	1.85 (1.05,3.24) *
30-34 years		1.57 (0.90,2.73)	1.86 (1.03,3.36) *
35 years or more		1.60 (0.90,2.83)	1.80 (0.98,3.31) *
Maternal height			
Short <=145 cm		2.72 (2.00,3.71) ***	2.61 (1.90,3.59) ***
Average 145.1-155 cm		1.00	1.00
Tall 155.1 & over		0.38 (0.30,0.48) ***	0.41 (0.32,0.52) ***
Maternal education			
Up to grade 5		1.00	1.00
Grade 6 to Ordinary Level		0.74 (0.44,0.93)	0.79 (0.53,1.18)
Advanced Level		0.53 (0.33,0.70) **	0.61 (0.37,0.98) *
Degree and above		0.65 (0.34,1.23)	0.77 (0.34,1.24)
Maternal employment status			
Employed		1.00	
Not employed		0.82 (0.64,1.04)	

Delivery method		
Normal	1.00	
Caesarean	1.19 (0.95,1.48)	
Household factors		
Ethnicity		
Sinhalese	1.00	1.00
Sri Lankan Tamil	1.11 (0.85,1.45)	1.00 (0.66,1.52)
Indian Tamil	1.94 (1.23,3.08) **	1.52 (0.80,2.86)
Muslims and others	1.48 (1.05,2.09) *	1.51 (0.98,2.11) *
Household size		
< 5 members	1.00	1.00
5-7 members	1.23 (1.00,1.51) *	1.21 (0.98,1.49) *
8 members and more	1.31 (0.88,1.95)	1.31 (0.87,1.96)
Wealth index		
Lowest	1.00	1.00
Second	0.88 (0.66,1.15)	0.94 (0.70,1.27)
Middle	0.84 (0.61,1.14)	0.92 (0.66,1.28)
Fourth	0.73 (0.53,1.01)	0.83 (0.58,1.17)
Highest	0.57 (0.37,0.86) **	0.70 (0.44,1.09)
Residential factors		
Residential sector		
Urban		1.00
Rural		1.12 (0.79,1.57)
Estate		1.21 (0.65,2.24)
Province		
Western		1.00
Central		1.46 (1.01,2.12) *
Southern		0.83 (0.54,1.20)
Northern		1.21 (0.66,1.87)
Eastern		1.10 (0.70,1.68)
North-Western		0.79 (0.51,1.18)
North-Central		0.79 (0.44,1.19)
Uva		1.00 (0.65,1.55)
Sabaragamuwa		0.90 (0.63,1.47)

P < 0.05 **P<0.01**P<0.001

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Table 6.9 presents the consolidated results of the Model 3 of each four child-mother pairs, with the aim of understanding parameters estimates, which is useful for the discussion

Table 6.9 Adjusted risk ratios (95% CI) of all final models of child-mother pairs

Covariate and category	**Stunted child/ underweight mother**	**Stunted child/ normal weight mother**	**Stunted child/over-weight mother**	**Stunted child/obese mother**
Intercept	0.10 (0.29,0.37)	0.14 (0.66,0.32)	0.07 (0.02,0.21)	0.01 (0.00,0.04)
Child factors				
Age in months				
6-11 months	1.00		1.00	
12-47 months	2.79 (1.27,4.63) **		0.92 (0.63,1.35)	
48-59 months	1.00 (0.43,2.31)		0.49 (0.30,0.83) **	
Birth weight status				
Normal	1.00	1.00	1.00	1.00
Low birth weight	3.83 (2.70,5.43) ***	2.60 (2.07,3.27) ***	1.81 (1.32,2.47) ***	1.52 (0.89,2.58) *
Maternal age				
<= 20 years	1.00	1.00	1.00	
21-29 years	0.99 (0.51,1.88)	1.85 (1.05,3.24) *	1.59 (0.74,3.43)	
30-34 years	0.46 (0.22,0.97) *	1.86 (1.03,3.36) *	1.92 (0.87,4.20)	
35 years or more	0.39 (0.18,0.87) *	1.80 (0.98,3.31) *	2.32(1.05,5.15) *	
Maternal height				
Short	1.99 (1.16,3.14) *	2.61 (1.90,3.59) ***	2.12 (1.40,3.22) ***	3.51 (1.93,6.40) ***
Normal	1.00	1.00	1.00	1.00
Tall	0.45 (0.30,0.69) ***	0.41 (0.32,0.52) ***	0.36 (0.26,0.50) ***	0.47 (0.28,0.80) **

Covariate and category	Stunted child/ underweight mother	Stunted child/ normal weight mother	Stunted child/over-weight mother	Stunted child/obese mother
Maternal education				
Up to grade 5	1.00	1.00	1.00	
Grade 6 to Ordinary Level	0.76 (0.41,1.39)	0.79 (0.53,1.18)	1.49 (0.79,2.81)	
Advanced Level	0.67 (0.31,1.46)	0.61 (0.37,0.98) *	1.07 (0.52,2.19)	
Degree and above	0.65 (0.15,2.52)	0.77 (0.34,1.24)	1.15 (0.47,2.81)	
Maternal employment status				
Employed				
Not employed				
Delivery method				
Normal				1.00
Caesarean				2.43 (1.56,3.79) ***
Ethnicity				
Sinhalese	1.00	1.00	1.00	1.00
Sri Lankan Tamil	1.28 (0.64,2.57)	1.00 (0.66,1.52)	1.38 (0.82,2.34)	1.32 (0.56,3.10)
Indian Tamil	1.86 (0.77,4.48)	1.52 (0.80,2.86)	1.21 (0.47,3.15)	1.58 (0.22,10.9)
Muslims and others	0.94 (0.42,2.09)	1.51 (0.98,2.11) *	2.46 (1.60,3.77) ***	3.26 (1.68,6.30) ***
Household factors				
Household size				
< 5 members		1.00		1.00
5-7 members		1.21 (0.98,1.49)*		1.67 (1.02,2.67) *
8 members and more		1.31 (0.87,1.96)		3.28 (1.59,6.78) **
Wealth index				
Lowest	1.00	1.00	1.00	1.00

Covariate and category	Stunted child/ underweight mother	Stunted child/ normal weight mother	Stunted child/over-weight mother	Stunted child/obese mother
Second	0.62 (0.39,0.98) *	0.94 (0.70,1.27)	0.78 (0.53,1.15)	2.09 (1.03,4.11) *
Middle	0.49 (0.27,0.78) **	0.92 (0.66,1.28)	0.66 (0.43,1.03)	1.66 (0.75,3.70)
Fourth	0.25 (0.13,0.48) ***	0.83 (0.58,1.17)	0.61 (0.39,0.97) *	1.80 (0.81,3.99)
Highest	0.18 (0.07,0.49) ***	0.70 (0.44,1.09)	1.03 (0.62.1.71)	2.05 (0.82,5.14)
Residential factors				
Residential sector				
Urban	1.00	1.00	1.00	1.00
Rural	0.65 (0.39,1.29)	1.12 (0.79,1.57)	0.94 (0.63,1.41)	0.84 (0.52,1.71)
Estate	0.72 (0.31,1.93)	1.21 (0.65,2.24)	0.64 (0.28,1.46)	0.52 (0.96,2.99)
Province				
Western	1.00	1.00	1.00	1.00
Central	1.38 (0.71,2.74)	1.46 (1.01,2.12) *	1.32 (0.83,2.10)	0.73 (0.32,1.66)
Southern	1.68 (0.82,3.09)	0.83 (0.54,1.20)	0.49 (0.27,0.88) *	0.60 (0.24,1.31)
Northern	0.59 (0.22,1.45)	1.21 (0.66,1.87)	0.66 (0.33,1.31)	1.47 (0.44,3.44)
Eastern	0.57 (0.22,1.31)	1.10 (0.70,1.68)	0.89 (0.52,1.53)	0.95 (0.39,1.97)
North-Western	1.72 (0.80,3.12)	0.79 (0.51,1.18)	0.99 (0.60,1.63)	0.50 (0.18,1.25)
North-Central	0.93 (0.35,2.12)	0.79 (0.44,1.19)	1.03 (0.58,1.81)	1.05 (0.41,2.38)
Uva	0.74 (0.32,1.69)	1.00 (0.65,1.55)	0.74 (0.41,1.35)	0.58 (0.21,1.66)
Sabaragamuwa	1.14 (0.57,2.41)	0.90 (0.63,1.47)	0.82 (0.47,1.44)	0.63 (0.25,1.75)

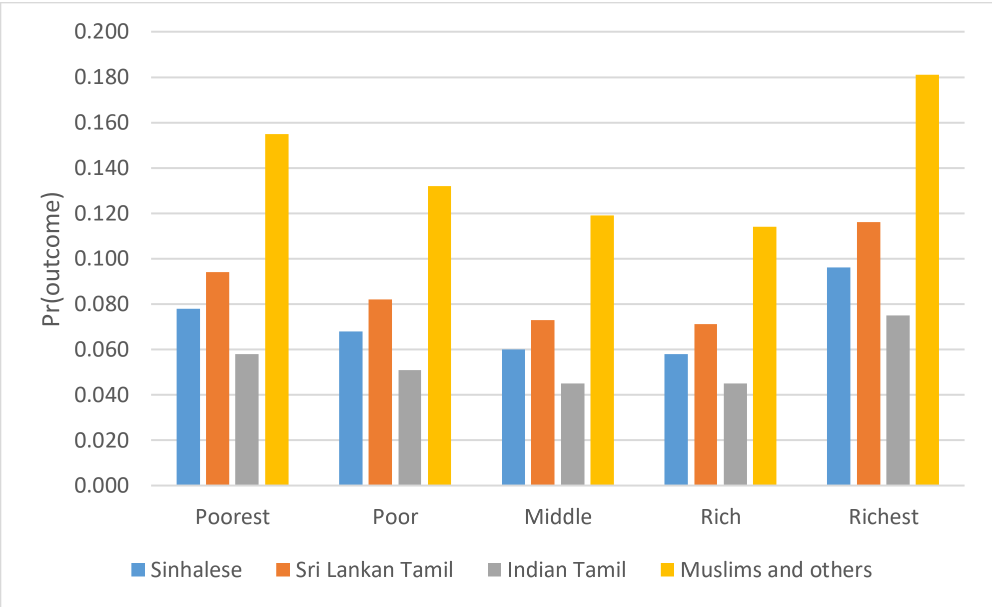
P < 0.05 **P<0.01**P<0.001

6.10 Predicted probabilities of a child being stunted and having an overweight mother by wealth and ethnicity

Further exploration of the predicted probabilities for having stunted child and overweight mother pairs across wealth quintile, by major ethnic groups was conducted (Figure 6.5). These predicted probabilities are calculated holding the other covariates constant at their mean values.

According to Figure 6.4, there is a U-shaped relationship between household wealth and the chance of having a stunted child/overweight mother combination. The lowest probability is among middle and somewhat richer households, and the highest probabilities are among the richest and then the poorest households. Muslim women are also at the higher risk of DBM, whilst Indian Tamils are at the lowest risk. This Figure also reflects that Indian Tamils have low probabilities of the double burden as these women are unlikely to be overweight, even though many of their children are stunted.

Figure 6.4 Predicted probability of a child being stunted and having an overweight mother by wealth and major ethnic groups



6.11 Child and maternal food patterns and association with the DBM

To identify the main food patterns identified by the children and mothers, data were extracted for the children who are aged 6-36 months old and their mothers. There was 2,300 sample of child-mother pairs who were available with data on food group intake 24 hours preceding the survey.

The following food groups were considered for the factor analysis (1) “grains, roots, and tubers” (comprised of soup/clear broth OR bread, noodles, other grains OR fortified food OR potatoes, cassava, tubers); (2) “legumes and nuts” (comprised of beans, peas, or lentils); (3) “dairy products” (comprised of formula milk OR tinned powdered/fresh milk; OR cheese, yoghurt, other milk products OR yoghurt); (4) “flesh foods” (comprised of liver, heart, other organ meat OR fish, dried fish, shellfish OR chicken,); (5) “eggs” (comprised of eggs); (6) “vitamin A rich fruits and vegetables” (comprised of pumpkin, carrots, squash OR dark green leafy vegetables OR mangoes, papayas, Vitamin- A fruits); (7) “other fruits and vegetables” (comprised of any other fruits);(8) Oil, fats, butter, products.

6.11.1 Child food patterns

Based on the eigenvalues of the PCA analysis (eigenvalues greater than one) and the interpretability of the factor loadings of the components, the PCA revealed three major dietary patterns after orthogonal rotation. These three major food patterns explained about 50.4 per cent of the variation in the total food intake of children. These patterns accounted for 21.5 per cent, 16.9 per cent and 12 per cent of the variation in the food intake, respectively.

These three food patterns were labelled based on the food categories that loaded highly as follows

- Pattern 1: Grain, vitamin A- rich fruits and vegetables
- Pattern 2: Legumes, other fruits, and vegetables
- Pattern 3: Flesh food and eggs

According to the results of the PCA analysis, it shows that the first patterns had positive loadings on all food items indicating that a higher factor score is associated with high consumption of a variety of foods. Therefore, it was used to develop a ‘food diversity score’. The association between the diversity score and the child mother pairs was tested and according to the results, there was no significant found between them (Table 6.10).

Table 6.10 Association between child-mother pairs and child food diversity score derived by PCA (%)

Child-mother pairs	Food diversity score based on first loading of the PCA					
	low (-4.01,-.64)	very low (-.63,.47)	high (.49,.95)	very high (0.97,1.16)	n	P-value
Stunted child-underweight mother	26.7	27.5	24.4	21.2	127	0.668
Stunted child-normal mother	24.9	27.3	22.9	24.6	409	
Stunted child-overweight mother	25.4	25.9	24	24.5	208	
Stunted child-obese mother	29	27.4	14.5	29	62	
Non stunted child-normal mother	25.1	23	25.5	26.3	1494	

6.11.2 Maternal food patterns

A similar procedure was followed to analyse maternal food patterns. The maternal food diversity score was also constructed based on 24-hour recall, using the same food groups. According to the results of the PCA, four major factor loadings were identified (after orthogonal rotation are shown) which accounted for 59 per cent of the total variation in the total food intake of the mother.

- Pattern 1: Legume, other fruits and foods made with oil, fat or butter
- Pattern 2: Eggs and vitamin A - rich fruits and vegetables
- Pattern 3: dairy and meat
- Pattern 4: grain and legume

These patterns individually contributed for 19 per cent, 16 per cent and 12 per cent and 12 per cent respectively. The first food pattern was used to develop a food diversity score, which is categorised into 25% for each quintile. The association between maternal food diversity score and nutritional status of child-mother pairs was checked and there was no significant association found between them. The major characteristics of respondents across the quintiles of food diversity score were explored using Chi-square analysis. According to the results (Table 6.11), maternal education, wealth, maternal ethnicity, sector and province were significantly associated with the food score based on the first loadings. For instance, there is a positive association between food score and maternal education; higher maternal education (Degree and above) is linked with higher food score. A similar pattern could be identified within the wealth quintiles, pairs in the lowest quintile were mostly belonged to the Indian Tamils in the estate sector.

Table 6.11 Association between maternal food diversity score derived by PCA analysis and other variables (%)

Variables	Food diversity score based on first loading of the PCA low (-1.97, -0.91)	very low (-0.90,-.0109)	High (.012,.7495)	very high (0.75,2.45)	n	P-value
Child-mother pairs						
Stunted child-underweight mother	31.5	19.6	25.8	22.8	127	0.592
Stunted child-normal mother	23.4	25.6	25.4	25.4	409	
Stunted child-overweight mother	26.4	26.4	24.5	22.6	208	
Stunted child-obese mother	32.6	20.9	29.0	17.7	62	
Non stunted child-normal mother	24.6	25.9	23.4	25.9	1494	
Maternal education						
Up to grade 5	31.9	28.5	26.7	12.9	116	0.000
Grade 6 to Ordinary Level	27.2	25.2	24.4	23.1	1557	
Advanced Level	19.1	25.5	24.1	31.1	497	
Degree and above	17.6	25.3	20.0	36.9	130	
Ethnicity						
Sinhalese	22.2	24	24.8	28.4	1527	0.000
Sri Lankan Tamil	33.8	30.0	21.4	14.7	476	
Indian Tamils	17.0	32.9	27.6	22.3	94	
Muslims and others	28.0	22.1	24.1	25.6	203	
Residential sector						
Urban	28.0	22.4	26.8	22.7	317	0.000
Rural	24.5	23.6	24.9	26.9	1804	
Estate	28.4	36.3	16.7	18.4	179	

Wealth Quintile						
Lowest	29.0	30.6	23.8	16.4	637	0.000
Second	25.3	23.6	29.5	21.3	477	
Middle	25.0	22.09	24.0	28.8	412	
Fourth	23.4	25.9	21.3	29.3	440	
Highest	20.0	21.8	21.2	36.8	334	
Province						
Western	20.7	23.7	28.5	27.0	400	0.000
Central	24.5	31.0	22.6	21.7	322	
Southern	16.7	24.5	34.5	24.1	269	
Northern	52.7	24.4	12.4	10.4	258	
Eastern	38.8	20.0	19.6	21.6	250	
North-Western	19.3	21.3	25.8	33.4	248	
North-Central	20.9	19.1	25.0	34.8	172	
Uva	23.2	30.2	20.5	25.9	185	
Sabaragamuwa	7.6	23.4	30.1	38.7	196	

P < 0.05 **P<0.01**P<0.001

6.12 Summary of key findings

This section summarises the third analysis results; the findings are discussed in Chapter 6 of this thesis.

- Regarding the first research question proposed by this study, the analysis explored the risk factors associated with the coexistence of stagnated child stunting rates and maternal overweight and obesity at the household level.
- The adjusted multinomial logistic regression models found that the child's age, low birth weight status, increased number of household members, delivery mode, wealth status, ethnicity, and residential province were significantly associated with any form of DBM at the household level.
- Predicted probabilities of a child being stunted and having overweight mothers were explored by wealth and ethnicity, which reflected that Muslim mothers from wealthier households were at a higher risk of DBM. In contrast, Indian Tamil mothers had low probabilities of the double burden as these women are unlikely to be overweight, even though many of their children are stunted.
- According to the third research question posed by this study, PCA analysis found two major food patterns for children such as grain, meat and vitamin A-rich fruits and vegetables, and mothers were preferred to have foods such as legume, other fruits and foods made with oil, fat or butter.
- The food patterns were not shown any significant association with child-mother pairs.

6.13 Strengths and Limitations

This study has some limitations. The cross-sectional nature of the data makes it difficult to evaluate the causal relationship between the outcome and explanatory variables. The DHS is a secondary data source, hence there could be some limitations with incomplete cases that could potentially bias the results. For instance, there is some missing information on children's HAZ records and maternal BMI status. Due to the exclusion criteria, we removed a large number of cases from our sample that could affect the representativeness of the sample. To check the representativeness of the subsample compared to the original sample, distributions of main characteristics (wealth quintile, BMI, child stunting, maternal education level, ethnicity, and province) were calculated. The percentages in each category of covariates appeared similar in each category although the numbers were different (Appendix M) presents the distribution of maternal BMI by child stunting status of the main DHS sample corresponds to Table 6.1). Also, the analysis considers births in the last 5 years, we do not know the accurate anthropometric status of the mother at the time of childbirth. However, mothers generally tend to gain weight after a birth, and these effects can be captured better in a panel or longitudinal type studies. In addition, errors could be arising on anthropometric measures, when using measurement instruments (weighing scales, tapes) and when reading and recording measurements. Therefore, additional measures such as head and circumferences, waist-hip measurements could have helped to gain better insights on child anthropometric data.

Another shortcoming was on BMI cut-off points. BMI measures are used in this study in measuring overweight and obesity that enables to compare of findings on DBM at the household level with other LMICs. However, some evidence suggested that BMI cut-offs are not necessarily accurate for some ethnic groups. In the case of Sri Lanka, it is reported that BMI cut-offs for obesity have underestimated the adiposity status of Sri Lankan adults (Jayawardena and Hills, 2020). Also, some predictors such as household dietary practices, food security, food expenditure, behavioural risk factors such as unhealthy diet and physical inactivity and childhood caregiving practices which could be potential drivers of DBM are not included in this study. In addition, there are inherent limitations for dietary pattern analysis (Thorpe et al., 2016). The magnitude of the recall bias in dietary data (24-h recalls) is unknown and correcting is impossible. The portion size was not available in the DHS data; therefore, energy intake could not be estimated.

Lastly, pairings such as non-stunted children with overweight, obese or underweight mothers and overweight children with underweight mothers were not considered in the bivariate and multivariate analyses of this study as these pairs were beyond its scope and with a limited number of cases. This may have led to underestimating the prevalence of household malnutrition in Sri Lanka.

Despite these limitations, the sample is adequate to warrant sufficient statistical power to understand information on the double burden of maternal over and child under-nutrition and its relationship with individual, socioeconomic and residential factors, which could be used as a basis for planning relevant nutrition interventions to the emerging DBM and malnutrition paradox at the household level in Sri Lanka.

Chapter 7 Discussion and conclusion

7.1 Introduction

This thesis has contributed to the knowledge of and understanding of bio-behavioural, socioeconomic and demographic factors underlying inequalities in child nutritional outcomes in Sri Lanka and draws the links between the prevalence of DBM at the household level, emphasising the associations and interdependencies of relevant factors. The Sri Lankan context is paradoxical, in that there are poor achievements in child nutritional outcomes alongside a satisfactory performance in other health outcomes (such as a low maternal mortality rate, and a low under-five mortality rate). In addition, there is little known about the socioeconomic inequalities underlying child nutritional outcomes in Sri Lanka and the emergence of the so-called *double burden of malnutrition* (DBM) at the household level which is not systematically investigated. This thesis used quantitative analyses of the 2016 DHS data which has island-wide coverage for the first time after the civil conflict ended in 2009. The first analysis addressed this gap by first investigating the extent of social inequalities underlying low birth weight (LBW) outcomes in Sri Lanka. The key hypothesis tested was whether children born in poor households and to the Indian Tamil tea plantation workers in the estate sector were more vulnerable to LBW outcomes compared to other children born in richer households in other rural areas and towns and cities.

The subsequent analysis sought to shed light on understanding the extent of inequalities in child stunting, wasting and underweight and how these were distributed across different socioeconomic groups, residential sectors and geographical regions, further exploring whether LBW exerted any influence on nutritional outcomes through early childhood. The final analysis investigated the individual, maternal, household and residential factors associated with DBM, more specifically the coexistence of child stunting and maternal overweight and obesity within the same household.

This concluding chapter aims to summarise the key research findings of the thesis and discuss the implications as well as the study limitations and scope for future research. Section 7.2 presents an overview of research design, reflecting on the main research objectives and research questions. Section 7.3 provides a discussion of the main findings of each chapter. Section 7.4 discusses the key contribution of the study, then section 7.5 addresses the implications of findings with an overview of policy and programme recommendations. The overall strengths and limitations of the study are discussed in section 7.6, and this section also suggests the proposals for further research.

7.2 Overview of the research design

This thesis presents findings in three interrelated chapters in a research paper format.

Table 7.1 summarises the main objectives, the research questions associated with each objective, research gaps and the main findings from this PhD project.

Quantitative approach was used throughout the thesis. This study used the data from the recent Sri Lanka Demographic and Health Survey, which was conducted in 2016, the first DHS survey to cover the whole island after the civil conflict ended in 2009. The data were not publicly available; hence they were obtained in person for research use from the Census and Statistics Department in Sri Lanka. Prior to opening the datasets, ethical approval was obtained from the University of Southampton Ethics and Research Governance Online (ERGO), under the submission ID 42179.

Throughout the analysis, the selection of explanatory variables and associations between them was based on the analytical framework presented in section 2.9, which was influenced by the UNICEF conceptual framework of undernutrition (UNICEF, 2013).

The main conceptual framework was presented in Chapter 2 and reiterated in each analytical chapter to display relevant associations between outcome variables and explanatory variables. It depicted the maternal bio-behavioural and social and child level factors as immediate determinates of birth weight, child nutrition and double burden malnutrition, amongst other broader variables, operating at different hierarchical levels including the distal (underlying) and intermediate and immediate levels.

Table 7.1 Overview of the research, by objective and research questions

Research objectives	Research questions	Gaps in knowledge	• Data & analytical methods	• Key research findings
Analysis 1: To investigate the socioeconomic inequalities underlying low birth weight (LBW) outcomes in Sri Lanka among socioeconomic groups, and across the residential sectors.	1. How is LBW distributed among different socioeconomic groups and across residential sectors and geographical provinces? 2. What is the nature of the association between maternal nutrition depletion and LBW outcomes? 3. What are the socioeconomic inequalities of LBW by different residential sectors?	• No recent systematic investigation on factors associated with LBW at the national level, cover the entire island since the civil conflict ended in 2009. • Few studies focusing on the determinants of birth weight, existing studies were mostly focused on specific settings, e.g. rural or hospital-based studies, often with small samples	• Demographic and Health Survey (DHS) data (2016-2017). • N = 7,713 newborns, birth weight data extracted from the child health development records available for 7,713 babies. • Birth weight classified as LBW (≤ 2500 g) and normal weight.	• Maternal BMI, stature, ANC visits, birth interval, sex of child, iron and folic acid supplementation, education, wealth and ethnicity were associated with birth weight status. • LBW was significantly higher in the estate sector compared with rural and urban areas. • Negative concentration indices suggest a relatively higher concentration of LBW in poor households in rural areas and the estate sector. • Results from random intercept models showed a strong correlation between the risk of LBW for children

Research objectives	Research questions	Gaps in knowledge	• Data & analytical methods	• Key research findings
	4. What are the maternal, socioeconomic and geographic factors associated with LBW at the maternal, household and community levels?	representative at a district or a hospital.	• Fixed effect binary logistic and random intercept three-level binary logistic regression models. • Health inequality measures: concentration indices and curves.	of the same mother, and only a weak community level correlation. • Effect of the maternal variables was larger than that of socioeconomic factors
Analysis 2: To examine the bio, demographic, socioeconomic and geographic factors associated with undernutrition in children aged under five years, and further to examine how these factors account for potential socioeconomic inequalities in child undernutrition in Sri Lanka.	1. What is the extent of inequalities in child undernutrition outcomes in Sri Lanka and how are these distributed across different socioeconomic groups and residential sectors? 2. What is the nature of association between low birth weight and undernutrition outcomes?	• Few studies on child undernutrition, restricted to a specific setting, lack of studies on the prevalence of undernutrition in Sri Lanka at the national level, covering the whole island. • None of the studies disentangle the community effect on	• Demographic and Health Survey (DHS) data (2016-2017) • N = 7,259 children aged 6-59 months Based on WHO definitions. • Stunted (height-for-age) * • Wasted (weight-for-height) * • Underweight (weight-for-age) * * Below minus two standard deviations (-2 SD) from the median of the WHO standard.	Significant predictors: • **Stunting**: child's age, low birth weight status, birth intervals, mother's body mass index (BMI), maternal stature, household wealth index, ethnicity, and geographic province. • **Wasting:** low birth weight, birth intervals, morbidity status, mother's BMI, maternal education and ethnicity. • **Underweigh**t: same as stunting, except that maternal education was

Research objectives	Research questions	Gaps in knowledge	• Data & analytical methods	• Key research findings
	3. What is the nature of association between child immunisation and child nutritional status? 4. What is the nature of association between infant and young child feeding (IYCF) practices and child nutritional status? 5. What are the maternal, socioeconomic and geographic factors associated with child undernutrition at the maternal, household and community levels?	child undernutrition outcomes	• Fixed effects binary logistic regression and random intercept three-level binary logistic regression models • Health inequality measures: concentration indices and curves	significant and ethnicity was not significant. • IYCF practices had a marginal effect on child undernutrition, while prolonged breastfeeding for 24-36 months had a risk of underweight. • Partial immunisation status during the first year of life was associated with decreased odds of underweight compared to full immunisation during 12-24 months. Immunisation effect was not significant once the age group was expanded to 12-59 months. • Random intercept models of child undernutrition confirmed that larger variation occurred between

Research objectives	Research questions	Gaps in knowledge	• Data & analytical methods	• Key research findings
				households within communities than between communities
Analysis 3: To examine how individual, maternal, household and residential factors are associated with DBM, more specifically the existence of child stunting and maternal overweight and obesity in the same household in Sri Lanka.	1. What are the risk factors of child stunting status and mother's overweight and obesity within the same household? 2. What are the factors associated with maternal overweight and obesity? 3. What is the nature of association between child and maternal dietary patterns and the prevalence of DBM?	• No recent analysis /cross –country comparison on the coexistence of the double burden of malnutrition at the individual or household level. • Few studies focusing on the dietary diversity of the children and maternal overweight and obesity, these studies are not nationally representative,	• Demographic and Health Survey (DHS) data (2016-2017) N=5,975 Considered the following pairs: • stunted child/ underweight mother • stunted child/normal-weight mother • stunted child/ overweight mother • stunted child/obese mother • Multinomial logistic regression models.	**For stunted child/overweight mother pairs:** • Child's age (48,59 months), low birth weight (LBW) advanced maternal age (35 and +), maternal stature (short) ethnicity (Muslims and other minorities), household wealth index (richer) and province (Southern) **For the stunted /obese pairs:** birth weight, maternal stature, household members, delivery mode **For the stunted child-underweight mother pairs**

Research objectives	Research questions	Gaps in knowledge	• Data & analytical methods	• Key research findings
		covering only certain districts.		Child age, birth weight, maternal age, maternal stature, ethnicity, wealth index **For the Stunted child-normal weight mother pairs** Birth weight, maternal age, maternal height, maternal education, ethnicity, household size and province

7.3 Discussion of main findings

This section chapter provides a discussion of all study findings in line with the analytical framework and the discussion is done outlining research hypotheses.

7.3.1 Social inequalities in low birth weight outcomes in Sri Lanka

This study has examined factors associated with low birth weight using hierarchical grouping (maternal, household and community levels), as illustrated in the analytical framework in Chapter 2. It also investigated the socioeconomic inequalities of low birth weight across different residential sectors. The definition of low birth weight for the purpose of this study was <=2500 grams (instead of <2500 grams) to account for potential heaping inherent in population surveys. The estimated mean birth weight (2917 grams) was found to be broadly in accordance with the estimate from a hospital-based study in Sri Lanka that reported a mean birth weight of 2,854 grams (Nanayakkara et al., 2011).

The present study used both multiple linear and logistic regression approaches to investigate the factors associated with birth weight and low birth weight outcomes. Also, a multilevel analysis was undertaken due to the hierarchical nature of the data. Overall results from the multivariate logistic regression analysis suggested that maternal factors have a strong influence on birth weight compared to socioeconomic and residential factors. For example, maternal depletion factors including maternal BMI, maternal height and birth interval were more influential in determining low birth weight than socioeconomic and geographic factors. On the other hand, results from the inequality measures indicated a socioeconomic gradient exists for low birth weight outcomes: mothers in the estate sector who in a disadvantaged socioeconomic position have an increased risk of having low-birth-weight. Results from the multilevel analysis explained more than 60 per cent of the variance at the maternal level. A relatively small community level variance (6 per cent) was attributed to the low birth weight outcome, despite significant differences between mothers within communities. This indicates that maternal level is more influential in determining the low birth weight in the context of Sri Lanka.

Child and maternal level factors

Both maternal and childbirth factors are treated as immediate factors, which directly influence low birth weight. With reference to the main objective of the study, this study found a strong relationship between maternal depletion factors and low birth weight prevalence. Maternal depletion, which is often reflected in poor maternal nutrition and health caused by successive pregnancies and childbirth, leads to deliveries of poor prognosis such as babies with low birth weight for gestational age (King, 2003).

This study identified proximate factors such as maternal BMI, height, preceding birth intervals, intake of micronutrients, anc visits and child sex which directly determined the maternal nutritional status. There was a significant association between LBW and women with low BMI and short stature in both linear and logistic regression approaches. According to these findings, women who have a shorter stature have higher odds of having LBW babies thus confirming findings reported elsewhere (Anuranga et al., 2012; Inoue et al., 2016; Kader and Perera, 2014). This study, however, reported that the average height of Sri Lankan women was 1.53 meters, which was less than the average mean height of 1.61 meters of mothers in the multicounty study used to generate the WHO growth standards (Rannan-Eliya et al., 2013). Hence, it is questionable to apply WHO Multicentre Growth Reference Study (MGRS) standards to assess the low birth weight for each population with different anthropometric measures. Therefore, in agreement with previous studies (Abeyagunawardena et al., 2018; Perera et al., 2014) the present study suggests the development of country-specific standards to assess birth outcomes, including low birth weight.

Previous research has found that poor birth outcomes arise from young women with a short interval between pregnancies (King, 2003). The present study found that mothers who have longer birth intervals had a lower risk of having low birth weight babies. The effect remained significant at each stage of analysis after controlling for other maternal, socioeconomic and geographic factors. The pathways can be explained through the concept of maternal depletion as when the pregnancies are closely spaced, the mother does not have adequate time to restore her depleted micronutrient stores from the previous birth. This in turn may exacerbate the risk of delivering a poor prognosis of low birth weight baby and vulnerability to continue in subsequent pregnancies (Winkvist et al., 1992). This could be applied to the estate mothers who are characterised by the shortest birth intervals (43 months) and who had the lowest median age at first marriage (23.3 years) compared to other ethnic groups (Department of Census and Statistics, 2017).

Another potential reason could be the parity. The current total fertility rate in Sri Lanka is 2.2 children per woman (Department of Census and Statistics, 2017). Thus, mothers who have achieved parity of two who may try for a subsequent pregnancy are less likely to have a short birth interval and may have a lower risk of delivering a low birth weight baby. However, due to the high correlation between parity and birth interval, it is difficult to disentangle the effects of parity in the current analysis.

Previous studies have also highlighted that micronutrient deficiencies exacerbate poor birth outcomes including low birth weight (Balarajan et al., 2013; Chhea et al., 2018; Gernand et al., 2016). Although the present study could not investigate the consumption of micronutrients due to lack of data, the analysis found that mothers who did not consume IFA were 1.5 times more likely to have a low birth weight baby when compared to mothers who received and consumed IFA. However, the effect was not significant once socioeconomic factors were controlled for. The government in Sri Lanka has taken several measures to improve the nutritional status of pregnant mothers, one such programme being the free distribution of "*Thriposha*" targeted at poor families. However, the current analysis found the effect of "*Thriposha"* not to be significant, consistent with findings from previous research (Anuranga et al., 2012). The effectiveness of the "*Thriposha"* programme is therefore questionable in terms of addressing the nutritional needs of mothers.

The results show that increasing the frequency of antenatal care clinics tends to decrease the probability of low birth weight outcomes, as also indicated by previous research (Chhea et al., 2018; Kader and Perera, 2014). The mean number of antenatal visits was reported as six in the present study. However, WHO has recommended a minimum of eight contacts during pregnancy (World Health Organization, 2016), which is still at a lower level compared to the minimum number of visits.

Apart from maternal depletion factors, other factors such as the child's sex and maternal education were found to be significantly associated with birth weight outcome. Consistent with previous studies, this study found that boys have a protective effect against LBW; girls were more likely to born as LBW babies. However, the biological mechanism for gender influence on birth weight is not clear. Less educated mothers may lack of dietary literacy, especially during their pregnancy. Limited education levels may also hinder access to antenatal visits such as an inability to adhere to health instructions given by doctors and/or a lack of autonomy in making decisions about their dietary needs (Chhea et al., 2018; He et al., 2018; Silvestrin et al., 2013). This study found that women with a GCE A Level qualification were less likely to have a low birth weight baby. This suggests that women with higher educational levels are more likely to have better knowledge about their nutrition and pregnancy care, as they have better socioeconomic status and greater autonomy to make decisions regarding their health.

Household level factors

Household wealth status was identified to have a strong influence on low birth weight when controlling for other maternal, socioeconomic and residential factors. The effect was more pronounced among mothers who had settled in the estate sector, even though the interaction effect was not significant. The negative concentration index also proved the inequalities in low birth weight outcomes, that poor households are more vulnerable to have low birth weight babies. It has been reported from previous studies that the estate sector has been mostly affected by poor undernutrition outcomes including low birth weight as nearly 1 in 3 babies are born as low birth weight babies (Jayawardena, 2014). The current study found that the odds of low birth weight among Indian Tamil mothers who predominantly lived in the estate sector were 1.62 times higher than the non-estate mothers belonging to other ethnicities. In addition, disaggregation of concentration curves by sectors also showed large between-inequalities in the estate sector and since the estate sector is homogeneously poor, it has slight within-sector inequalities compared to the other sectors. These findings support our hypothesis that children born in poor households and to the Indian Tamil mothers in the estate sector are more vulnerable to LBW outcomes than their counterparts living in richer households in other rural and urban areas. As depicted in the analytical framework, results confirmed that low birth weight is rooted at the household level: economically vulnerable households, particularly those of Indian Tamil ethnicity, are predisposed to poor nutritional conditions that may result in low birth weight outcomes.

Estate Indian Tamils descended from South India and migrated to Sri Lanka to work as estate labourers in the plantation sectors in the 19th century. They generally represent the economically deprived, poorest and lowest caste group in South India. Elsewhere, genetic factors may affect the persistence of having low birth weight babies in this ethnic group, as has been shown to be the case among the generations of Asian female migrants in the UK (Anuranga et al., 2012; Leon and Moser, 2012). However, in Sri Lanka, the effect of genetic factors on low birth weight is still unclear (Family Health Bureau, 2013), which suggests a need for a proper mechanism to monitor the contribution of epigenetic factors across all population categories with special emphasis on a vulnerable population.

Geographic and community level factors

In terms of the distal factors associated with birth weight, residential sector was found not to be statistically significant after controlling for other covariates, particularly ethnicity. The potential reason could be that the majority of Indian Tamils represent the estate sector.

According to the multivariate and multilevel results, LBW rates were more common in the Sabaragamuwa region and less common in the Northern region. For instance, this study found that mothers who were settled in Sabaragamuwa Province have higher odds of delivering low birth weight children (AOR 1.35, 95% CI 1.03 to 1.80) compared to mothers in the Western Province in Sri Lanka, after controlling for other covariates. This is perhaps due to the high concentration of Indian Tamils who live and work in Sabaragamuwa, one of the largest Tea growing regions in Sri Lanka. Thus, the results support the conclusion that being an Indian Tamil mother who lives in the estate sector in Sabaragamuwa Province, and who is disadvantaged in terms of income and nutrition, results in an increased likelihood of having a LBW infant. However, in contrast to previous findings, this study found community education and poverty were not significantly associated with low birth weight prevalence (Kayode et al., 2014; Young et al., 2010). Thus, it suggests policies should be more centred on improving maternal factors including nutritional level.

7.3.2 Understanding inequalities in child undernutrition outcomes in Sri Lanka

With reference to the second analysis of this thesis, the analytical framework illustrated the pathways associated with child undernutrition outcomes in the context of Sri Lanka. The main objective of the analysis was to examine the determinants of undernutrition outcome among children aged under 5 years (6-59 months) and further examine how certain determinants account for potential socioeconomic inequalities in child undernutrition outcomes. 0-5 month old infants were excluded due to practical and technical difficulties in measurements (Lopriore et al., 2007; Mwangome, 2014). For instance, errors may arise when using baby-weighing measurement and instruments while reading and recording measurements of height and weight. Errors when measuring length could be plausible as very young infants are difficult to measure and their parents may be reluctant to allow them to be measured. Moreover, it is still widely reported that breastfeeding acts as a protective factor against early malnutrition until approximately 6 months of age (Lopriore et al., 2007).

Overall, the results confirmed that the prevalence of child undernutrition in Sri Lanka has not shown a significant improvement between 2006 and 2016. According to the present study, the rates of stunting, wasting, and underweight were found to be 18.2 per cent, 14.5 per cent, 20.7 per cent respectively for children aged 6-59 months old. The prevalence of concurrent stunting, wasting and underweight among children aged 0–59 months was reported as 3.3 per cent.

In relation to the first research question on examining the determinants of child undernutrition outcomes proposed for the second analysis in this thesis, child’s age, birth weight, birth interval; mother’s BMI, and maternal stature; household wealth quintile, ethnicity and province were significantly associated with stunting. For wasting, which reflects acute malnutrition, factors such as birth interval, birth weight, mother’s BMI, maternal education, and ethnicity were found to be significant predictors. child morbidity status was positively associated with child wasting: namely, children who have recently contracted a disease have increased odds of being wasted (Harding et al., 2018; Myatt et al., 2018). Our analysis found that the underlying determinants of stunting are similar to those for underweight except for child ethnicity which was not significant after adjusting for other factors. Overall, stunting varies a lot more among different subgroups of the population than wasting and underweight.

With reference to the research objective of assessing inequalities in child undernutrition outcomes, the present study demonstrated that concentration indices (CIs) are negative for all child nutritional outcomes, indicating that poor nutritional outcomes are more concentrated among poor households. These inequalities are mostly manifested in long term growth failures (chronic malnutrition or stunting and underweight) rather than in short term growth failures or wasting. Nevertheless, absolute values of the CIs showed a downward trend at the nutritional level compared to the 2006 CI value (Jayawardena, 2020). This could be attributed to increased access to health services and the development of healthcare facilities in Sri Lanka. However, inequalities among the poorest wealth quintile still exist and are higher than the richest wealth quintile. The present findings suggest evidence of possible long-term health and nutrition problems among lower socioeconomic groups that broaden the gap between rich and poor (Jayawardena, 2020). Disaggregating analysis by the residential sector confirmed that the estate sector has the smallest level of socioeconomic inequality within it, as households within the estate sector are predominantly poor. Consequently, the estate sector has the lowest level of inequality in nutritional outcomes; however, inequalities in the estate sector are greater between sectors. These findings are consistent with national studies which reported the highest socioeconomic inequalities in estate sector compared to other sectors. According to the 2016 Household Income and Expenditure Survey (HIES), the poverty headcount Index (percentage of the population below the poverty line) is the highest in the estate sector (8.8 per cent) compared to urban and rural sectors (1.9 per cent and 4.3 per cent respectively). The mean household income per month in the estate sector is reported as Rs. 34,804 (approximately 174$), which is considerably lower compared to the urban sector (Rs. 88,692) and rural sector (Rs. 58,137) that may potentially constitute socioeconomic inequalities in the nutritional status of children in the estate sector compared to urban and rural sectors (Jayawardena, 2014; Rannan-Eliya et al., 2013).

Child and maternal level factors

Referring to the analytical framework of the study, immediate factors such as maternal and child factors are shown to have a close relationship with child stunting. Mothers with poor nutritional status significantly contributed to child stunting and underweight. Maternal height was a predictor of a child's nutritional status that indicates the intergenerational linkage between a mother's nutritional status and that of her child (Addo et al., 2013; Khan et al., 2019; Khatun et al., 2019; Prendergast and Humphrey, 2014). Mothers with poor anthropometry (BMI and height) may have reduced protein and energy deposits and small reproductive organ sizes, which in turn restrict proper fetal growth and exacerbate adverse birth outcomes and child growth failures (Addo et al., 2013).

The strong relationship between maternal BMI and child stunting and underweight is exemplified in the present study, suggesting an intergenerational cycle of malnutrition in Sri Lanka, which is consistent with findings reported by previous studies (Jayawardena, 2014, 2020). The correlation between maternal and child height is strongly intertwined by genetic factors. Rannan-Eliya (2013), claims that a substantial part of the stunting observed in Sri Lanka might be attributed to the genetic influence of previous generations (Rannan-Eliya et al., 2013). Our analysis also revealed that child wasting was not associated with maternal height, but with maternal BMI as reported elsewhere (Ali et al., 2017), which may reflect the current nutritional inadequacy of children that results in child wasting.

The present study also found that children who were born as LBW babies are at substantially increased risk of remaining undernourished during their early years even after controlling for other children, maternal/household and community characteristics. The pragmatic relationship between birth weight and child undernutrition is in line with previous studies carried out in numerous settings including Zambia and India (Manda et al., 2016; Rahman et al., 2016; Ramakrishnan, 2004). The present study also confirmed the strong association between LBW and child stunting. However, low birth weight children in Sri Lanka exhibit a recovery from stunting between ages three and five years, which is also similar to the results reported elsewhere (Desmond and Casale, 2017).

When the other childbirth factors are considered, it is found that the probability of stunting and underweight increased with age, peaking at around 12-36 months, when it is significantly higher than in children aged less than 6 months. Also compared to first births, children at other parities with higher preceding birth intervals were significantly more likely to be undernourished. However, the highest odds of undernutrition are reported for children born at an interval of 24-47 months; the odds then tend to decrease after an interval of 47 to 49 months. This is coherent with other studies and suggests that competition for food allocation within a household and mother may fail to fulfil the nutritional needs of other children (Sultana et al., 2019).

A large number of studies have highlighted the fact that wasted children are at increased risk of morbidity, especially infectious diseases (Mahumud et al., 2017; Tariku et al., 2017). On the other hand, present study indicates that wasted children are suffered from diarrhoea, fever or cough. This reflects that frequent or prolonged illnesses may restrict the proper weight-for-height growth. Child morbidity status had no impact on stunting and underweight prevalence.

In terms of IYCF practices, exclusive breastfeeding is reported at 84 per cent which is the highest rate in South Asia. The multivariate logistic results showed little or no significant association between exclusive breastfeeding and child undernutrition indicators. Children experiencing prolonged breastfeeding (breastfeeding beyond the first year of life) had a greater risk of being undernourished, a result that aligns with previous studies conducted in developing countries (Brown et al., 1995; Khan and Islam, 2017). Prolonged breastfeeding could be disproportionately concentrated in poor households, with less educated or working mothers, hence the breastfeeding effect should disappear when other covariates are controlled for (Caulfield et al., 1996). The other reason could be reverse causality in terms of infant size and subsequent breastfeeding: mothers continue breastfeeding their children who are not considered to be thriving (Caulfield et al., 1996; Kramer et al., 2011). Therefore, the timing of the onset of complementary feeding, nutrients composition of the food and the frequency of feeding should be considered.

Other IYCF indicators were assessed, and it was found that minimum meal frequency and minimum dietary diversity in Sri Lanka were high compared to the other South Asian countries (World Health Organization, 2017a). The main food was found as grain, while consumption of flesh foods, eggs and other fruits and vegetables was found to be low, agreeing with other studies conducted in Sri Lanka and South Asia (Aguayo, 2017; Senarath et al., 2012). However, IYCF indicators had a negligible impact on child nutritional outcomes, consistent with another national study (Rannan-Eliya et al., 2013). The effect was also consistent with studies in Cambodia, Ethiopia, Ghana and Mexico (Reinbott et al., 2015; Saaka et al., 2015; Tessema et al., 2013). In addition, consistent with previous studies, the estate sector had the lowest dietary diversity and minimum meal frequency compared with other sectors (Senarath et al., 2012). Researchers argued that the recall bias of the question on feeding practices (which is based on 24-hour recall) results in answers that do not reflect the whole situation of feeding practices, a fact that might explain the lack of association between some IYCF indicators and child anthropometric measurements (Rakotomanana et al., 2017). Nevertheless, in the case of Sri Lanka, it is suggested that household poverty could affect access to food and the regional disparities, particularly lack of affordability and poor access to food, should be identified and addressed (Rannan-Eliya et al., 2013; World Health Organization, 2017a).

Further, the relationship between child nutrition and immunisation in the first year of life was analysed in this study. In contrast to other studies, this analysis indicates that having all recommended immunisations during the first year of life appears to be associated with an increased risk of child underweight for children aged 12-24 months compared to partial immunisation. This finding contradicts the evidence reported by previous studies conducted in multiple settings which established the fact that partial immunisation is associated with a higher prevalence of underweight in India (Anekwe and Kumar, 2012) and Angola, Chad, Ethiopia, Guatemala, Kenya, Myanmar, and Senegal (Solis-Soto et al., 2020). The potential reasons that could explain the effect of partial immunisation include: barriers in accessing the health care system (not having adequate clinics, providers); fear of long term immunisation-related consequences; and belief that a healthy child who is thriving may not need to be immunised as it interferes with the child’s natural development or natural recovery from disease (Anderson, 2014; Lehmann et al., 2017). However, in the context of Sri Lanka, the association between partial immunisation and child nutritional status was not properly investigated. The association between receiving recommended immunisations and child undernutrition for children aged 12-59 months was insignificant, implying that protection from the immunisation can naturally decrease over time and it is therefore important that immunisations are given at the recommended age without postponement, consistent with previous findings (Berendsen et al., 2016).

Among the other immediate factors at the maternal level, maternal education plays a vital role in determining child nutritional outcomes, particularly wasting and underweight. In the multivariate models, mothers who passed a degree and above were less prone to have wasted or underweight children, which has already been established in other national and international studies (Iftikhar et al., 2017). The possible explanation could be that literate mothers are more knowledgeable about their children’s nutritional needs and are able to provide better health care facilities for their children. Also, educated mothers have increased opportunities to make comparative decisions about available health practices for their children (Jayawardena, 2020; Rannan-Eliya et al., 2013).

Household level factors

When considering household level factors, our study showed that the household wealth index was significantly associated with stunting and underweight. This is in accordance with previous findings in Sri Lanka (Jayawardena, 2020; Rannan-Eliya et al., 2013) and other international studies using DHS data (Black et al., 2008; Khan et al., 2019; Vollmer et al., 2017). This suggests that socioeconomic status plays a crucial role in child undernutrition. Children from poor households with limited access to food and health services are more vulnerable to growth failures. Therefore, it is essential to focus on improving the nutritional status of poorer children when implementing poverty alleviation programmes (Jayawardena, 2020; Khan et al., 2019). This study did not find any strong relationship between wealth and child wasting, a fact which is inconsistent with previous studies that widely refer to wealth as a determinant of wasting (Harding et al., 2018; Martorell and Young, 2012). The possible reason could be that child and maternal factors including low birth weight and maternal BMI are the foremost predictors of wasting and once they are controlled, asset ownership is no longer important. This is consistent with studies conducted in South Asia, including Bangladesh, India, the Maldives, Nepal, Pakistan and Afghanistan (Harding et al., 2018; Martorell and Young, 2012).

Children of Indian Tamil ethnicity settled in the estate sector have the highest odds of being stunted, supporting the evidence from other studies conducted in Sri Lanka. For example, the prevalence of stunting among Indian Tamils (where over 82.7% of Indian Tamils live in the estate sector) was 39.7%, more than twice as high as among those from other ethnic groups. The results of the multivariate logistic regression models for stunting also confirmed that the odds of childhood stunting increased by 50 per cent for Indian Tamil children compared to other ethnic groups. On the other hand, concentration curves and indexes have confirmed that Indian Tamils living on estates remain markedly disadvantaged. This may confirm a significant relationship between poverty and ethnicity, that in turn is related to stunting. Hence, the findings partially support the study hypothesis that children living in poor households and born to Indian Tamil mothers who live in the estate sector have higher risks of stunting. However, interactions between ethnicity and household wealth were insignificant.

Ethnic differentials in child undernutrition existed: children from Muslim and other ethnic backgrounds also showed a higher risk for stunting than Sinhala children, however, these children had lower odds of being underweight and wasting compared to their Sinhalese counterparts. This may be due to some cultural factors represented in these ethnicities reported elsewhere (Fantay Gebru et al., 2019; Mkandawire and Hendriks, 2018).

The results of the separate analysis on household environmental factors showed that unimproved water, source of cooking and availability of livestock are associated with child stunting and underweight, however, the effects were not strong. Factors such as maternal employment status, marital status, antenatal care visits, receiving iron and folic acid, and household size were not significantly associated with any of the child nutrition indicators.

Geographic and community-level factors

Considering the distal factors, disagreeing with previous findings, this study found no significant association between residence and child nutritional outcomes, once all the other covariates were adjusted. At the regional level, children in Central Province are more likely to be stunted. The potential reason could be that Central Province is dominated by the estate sector: it is predominantly plantations where the majority of people of Indian Tamil descent work and live (World Bank Group, 2017). This sector is often identified as a disadvantaged group with poor health care facilities and access compared to the Western Province. For example, as Jayawardena (2014) discussed, 17 per cent of households have no safe drinking water and 22 per cent have no poor sanitary facilities. In addition, 46 per cent of women in the estate sector have below primary education (Jayawardena, 2014; Rajapaksa et al., 2011). This disadvantaged situation could increase the risk of long-term childhood growth failures in Central Province.

Multilevel models were fitted due to the nested nature of the data and the interpretation of parameter estimates remains stable; however, some of the effects are attenuated. Community education and poverty were not significantly associated with the child nutritional outcomes. Results suggested that individual, maternal and household-level characteristics are more important than community-level factors in explaining child undernutrition. For instance, null models showed that more variation occurs between households within the same community than between communities. This finding is consistent with Smith and Shively (2019) who point out the relatively smaller variation at the community level on child anthropometric measurements such as height-for-age and weight-for-height in Nepal. It is also aligned with findings reported by previous studies which suggested considering individual, household and community variations in predicting child undernutrition (Mokgatlhe and Nnyepi, 2014; Smith and Shively, 2019).

The findings provide useful methodological insight for policymakers to understand the relationship between child-level undernutrition measures and maternal, household and community level covariates in Sri Lanka. Further investigations using longitudinal data and systematic nutritional monitoring are required to address the burden of undernutrition among children in Sri Lanka.

7.3.3 The double burden of malnutrition: the coexistence of stunted children and overweight and obese mothers in Sri Lanka

Sri Lanka is a country that has shown better health achievements compared to its peer South Asian countries and most LMICs. Taking into consideration per capita income compared with the average for LMICs, Sri Lanka was upgraded to an upper-middle-income country in 2020. However, despite the improvements, the prevalence of childhood undernutrition remained unchanged, while overweight and obesity in women in the reproductive age group showed a steady increase with the escalation of NCDs. The main objective of this study was to explore the DBM at the household level in Sri Lanka, particularly the prevalence of the familial co-existence of child stunting and maternal overweight and obesity by investigating the relationship between child, maternal, household and residential factors and the DBM. In addition, we were able to examine other forms of child-mother pairs such as stunted child/underweight mothers, stunted child/normal weight mothers and non-stunted child/normal weight mother pairs.

The foregoing investigation of DHS data shows that the co-existence of child stunting and overweight mother in Sri Lanka stands at just 8.3 per cent, and the number of stunted child and obese mother pairs was very low (2.8 per cent). While this is low, DMB within the same household is emerging as a trend in Sri Lanka. The emerging figures of DBM in Sri Lanka correspond to the national figures of concurrent child stunting and maternal overweight in Asian, African and Latin American countries including Bangladesh, Nepal, Pakistan, and Myanmar (Anik et al., 2019), Guatemala and Ghana (Atsu et al., 2017; Jehn and Brewis, 2009; Lee et al., 2010). The present study has demonstrated that Sri Lanka faces a paradoxical situation of undernutrition and over (mal) nutrition within the same household, a trend emerging and likely to increase in the future. As the stagnated child undernutrition rates already stand as a public health challenge in Sri Lanka, the paradoxical malnutrition situation at the household level poses an additional health challenge that should be addressed in national nutritional policies and interventions.

Child and maternal level factors

When the child immediate factors are considered, dual burden pairs are, not surprisingly, associated with the predictors of stunting such as child age, low birth weight status consistent with previous studies conducted in LMICs (Doak et al., 2016). There was a strong positive association between LBW and stunted child and other mother pairs. Thus, children who are born with LBW are at an increased risk of remaining undernourished in the early years of their childhood even after controlling for the child, maternal, household, and residential or community characteristics. The negative relationship between birth weight and childhood undernutrition established in this study aligns with other studies conducted elsewhere (Doak et al., 2016; Ntenda, 2019). Low birth weight status is also significantly associated with maternal BMI levels, reflecting the relationship that low birth weight children are likely to be stunted when the mother is overweight or obese. Other child factors such as birth interval and child’s sex are not significantly associated with the DBM at the household level nor the other pairs. However, previous studies highlighted that the sex of a child is associated with DBM pairs, although the findings of previous studies were not always consistent with each other. For example, Atsu et al. (2017) and Oddo et al. (2012), found that female children were more likely to have overweight mothers while Irarrazaval et al. (2018) found that male children tend to be part of DBM pairs (Irarrázaval et al., 2018).

There was no consistent effect of the child’s age in the present study, contrary to the findings reported by Oddo et al., (2012) who found that an older age was a predictor of DBM at the household level. For example, children who are aged over 12 months are less likely to be associated with stunted child-overweight mother pairs, compared to younger children aged 6-11 months. However, the effect was opposite for the chance of being in stunted child/obese mother pairs in Sri Lanka.

In terms of maternal factors associated with the probability of having DBM pairs, short maternal stature was significantly associated with stunted child-overweight (SCOWT) mother pairs and stunted child-obese (SCOB) mother pairs. This is consistent with the previous findings of Ferreira et al. (2009) and Oddo et.al (2012) that BMI is higher among women with short stature, which reflects malnutrition in early life. Stunting appears as an intergenerational phenomenon that could transfer from mother to child (Ferreira et al., 2009; Oddo et al., 2012; Sunuwar et al., 2020). Mothers characterised with short stature are potentially exposed to chronic diseases and they may give birth to babies who have been less well-nourished in the womb compared to women with normal stature (Sunuwar et al., 2020). These children consequently grow into overweight or obese adults. This mechanism reflects Barker's Developmental Origins of Health and Disease (DOHaD) on how early life exposures affect diseases in adulthood (Barker, 2012; Ferreira et al., 2009; Sunuwar et al., 2020). Whatever the underlying mechanism, evidence from this study clearly shows that maternal stature plays an important role in child undernutrition.

Turning to the other maternal factors, the results of this study demonstrated that households with mothers of advanced maternal age have an increased risk of being in stunted child/overweight mother pairs, while older mothers are less likely to be in stunted/underweight mother pairs compared to young mothers. However, the effect of the mother's age was not significant in this study when considering the stunted child/obese mother (SCOB) pair. This suggests that older women tend to have higher BMIs than younger mothers. This aetiology has been confirmed in numerous settings, demonstrating that overweight and obesity are commonly found in ageing women (Hauqe et al., 2019; Sunuwar et al., 2020). It is also aligned with another study encompassing five LMICs (Brazil, Guatemala, India, the Philippines, and South Africa), which indicated that advanced maternal age increased the risks of low birth weight as well as stunting in infancy (Fall et al., 2015).

Maternal educational or employment status did not seem to have a strong association with DBM in Sri Lanka. Mothers who had completed A levels have 49 per cent less likelihood of having stunted child-underweight mother pairs, compared to mothers who had only completed primary education. This confirms the finding in Sri Lanka that mothers with a lower level of education tend to have stunted children compared to mothers who are more educated (Shinsugi et al., 2019).

The present study also found that the Caesarean section was significantly associated with SCOB pairs, as it has an increased risk of 2.65 times compared to normal delivery. This finding is consistent with previous studies which claimed that both forms of malnutrition are linked with gut microbiota alterations in children (Das et al., 2019; Pekmez et al., 2019).

It has been already established from previous studies that high dietary diversity is associated with obesity in Sri Lanka and dietary patterns. However little or no attention has been given to investigating how dietary patterns are associated with the coexistence of the double burden at the household level. Therefore, key dietary patterns were identified for both children and mothers and their association with the double burden pairs. Children were more likely to score high on foods such as grain, vitamin A-rich fruits and vegetables. Using PCA, more dietary patterns were identified in mothers than children, perhaps indicating variation in the dietary intake of mothers. These dietary patterns are consistent with those previously described in the literature. For instance, grain (primarily rice) is the staple food in Sri Lanka which is identified as the most consumed food by children (Sirasa et al., 2019), providing more than half of their calorie supply. These results are consistent with the previous study of children in finding that they are more likely to consume grain, legumes and other fruits and vegetables than meat or eggs. However, children's food diversity score did not show any significant association with the child-mother pair's nutritional status.

Mothers are likely to consume legumes, fruits and foods made with oil, fat or butter. Such a diet high in oil, fat or butter might include saturated fatty acids that could be a risk factor for coronary heart disease (Houston, 2018). However, maternal dietary score was not significantly associated with the nutritional status of child-maternal pairs. Data on increased consumption of unhealthy foods and sugary drinks which are not captured in the DHS survey could also be a possible explanation for this. Nevertheless, maternal food diversity was shown to be strongly associated with other factors such as maternal education, wealth, residence and province. Households with higher incomes tend to have a better maternal dietary score than poor households, while households with lower levels of education, of Sri Lankan Tamil or Indian Tamil ethnicity and living in the estate sector, exhibit a poor food diversity score.

Household level factors

In terms of intermediate factors, a stunted child/underweight mother pair is less likely to feature in a richer household, whereas poor households are less likely to have a stunted child/obese mother pair. However, household wealth status did not have a consistent impact on the chance of a household containing a SCOWT pair or a stunted child/normal weight mother pair. This finding differs from some studies in Asian, African and Latin American countries, where it was found that

DBM at the household level is mainly entangled in lower wealth index groups who are economically disadvantaged (Angdembe et al., 2019; Subramanian et al., 2007). In addition, this finding could indicate that the main problem is not poor food quality, but rather insufficient quantities of food consumed in the poorest households, as is often reflected in poor households in Asian and African regions (van 't Riet et al., 2001; Zhou et al., 2020).

Ethnicity was found to be a strong risk factor for the DBM at the household level as Muslim mothers have an elevated risk of being in a SCOWT or SCOB pair. Predicted probabilities of SCOWT pairs by wealth groups and ethnic groups also showed that Muslim women are at the highest risk of this combination of the double burden. This could be attributable to the different energy intakes among various ethnic groups that underpin their cultural eating habits: Muslims in Sri Lanka tend to have a higher energy intake, higher dietary diversity and eat more fat-rich foods (Jayawardena et al., 2014; Sirasa et al., 2019).

In addition, among other pairs studied, Indian Tamil mothers are more likely to be in stunted child/underweight mother pairs. The possible reason could be the highest malnutrition and nutritional deficiencies in the estate sector, where people often live with poor dietary diversity and socioeconomic disadvantages (Jayawardena, 2014; Jayawardena et al., 2014).

Geographic and community-level factors

When the distal determinants are considered, paradoxical pairs are more common in urban settings. We found that DBM pairs with overweight and obese mothers are more common in the urban sector (8.9 per cent and 4.3 per cent of households respectively). However, this study also found that the residential sector became insignificant after adjusting for the child, maternal and household confounders. Results from the multivariate analysis revealed that Southern Province was significantly associated with SCOWT pairs. However, the regional effect was not strong, once all the covariates were adjusted to the final model. The lack of significance of the regional effect could be explained by the fact that immediate factors such as maternal stature, ethnicity and wealth may have taken up the regional effect.

7.4 Key contributions of this study

Sri Lanka has achieved substantial improvement in most health indicators, including maternal, child and neonatal mortality and life expectancy during the last decade compared to the other South Asian countries. There has been a dramatic change in the health and economic conditions in Sri Lanka. Sri Lanka was able to achieve most of the Millennium Development Goals (MDGs) related to health. The robust universal health care system, which gives free access to health care for all citizens has been a priority of successive governments resulting in a hundred per cent coverage of health services including maternal and antenatal care services, vaccine preventable diseases and NCD prevention and control. The total expenditure on healthcare has increased in recent years compared to other LMICs. Apart from these health achievements, Sri Lanka has been recently upgraded to upper middle-income country, having made drastic changes in economic indicators including great success in poverty reduction.

However, having reduced infant mortality, the focus needs to be on the nutritional outcomes of surviving children. Child nutrition remains an "unfinished agenda"; combating low birth weight and other child undernutrition outcomes over the last decades is an unresolved paradox, as well as an unresolved chronic human development and policy issue in Sri Lanka. Notwithstanding the persistent problem, the rise in overweight and obesity predisposes the population to higher risks of NCDs, given that it is one of the leading risk factors for excess mortality. At the same time, inequalities are evident in health and nutrition outcomes between different social and ethnic groups, which have not been previously investigated at the national level in post-war Sri Lanka.

There are some key contributions from this study pertaining to the present context in Sri Lanka. This study found socioeconomic inequalities in low birth weight and child undernutrition. There are marked inequalities in child low birth weight outcomes, which particularly affect those residing in poor households and those in the estate sector who mainly belong to the Indian Tamil ethnicity, a finding consistent with the previous studies conducted in Sri Lanka (Anuranga et al., 2012; Jayawardena, 2014). These inequalities pose a major challenge in terms of healthy survival, quality of life and well-being at the society level and ultimately for sustainable economic growth.

Also, the first two analyses highlight the intergenerational nature of malnutrition: poor nutritional status of mothers during pregnancy (including maternal depletion factors) leads to an elevated risk of having low birth weight babies. These babies could potentially be undernourished and remain in the vicious cycle of malnutrition. The intergenerational cycle of child undernutrition is evident among those born in poor households within the estate sector. Indian Tamil mothers living in the estate sector have generally poor nutritional status, and they may not have a sufficient supply of nutrients that are essential to maintain the balance between the needs of the mother and the fetus. These mothers may also be nutritionally depleted due to their close spaced pregnancies. Estate Indian Tamil mothers, who have the shortest preceding birth intervals compared to other sectors, may not have had adequate time to replace required nutrients used during the previous pregnancy. These women are likely to have low birth weight babies who suffer subsequent consequences of growth retardation and then continue to become undernourished adults. As such, the vicious cycle of malnutrition continues in Sri Lanka. This finding is key because it helps to identify the life cycle effect of nutrition that should be addressed to break the cycle of undernutrition and therefore supports a recommendation to policy makers for life course interventions.

Another key finding of this study is the insignificant effect of Thriposha - a large scale supplementary feeding programme for pregnant and lactating mothers and undernourished children below 5-years. This finding is important in understanding the effectiveness of such nutrition interventions to combat child undernutrition in Sri Lanka.

This study further sheds light on the double burden of malnutrition from both a child and a maternal perspective, whereas previous studies in Sri Lanka have distinguished interventions for mothers from those for children. Moreover, this study is the first to investigate not only the double burden of malnutrition among children and their mothers in Sri Lanka, but also the coexistence of malnutrition of children and mothers in the same household at the national level. Ethnic and other differentials in DBM are identified and it has been revealed that the Muslim population ethnicity has a greater likelihood of having DBM pairs irrespective of their wealth status, whereas Indian Tamils have low probabilities of having DBM pairs. This is another significant finding that helps to understand the differentials of DBM, which is currently lacking in Sri Lanka.

To the best of our knowledge, this is the first national study in Sri Lanka to demonstrate how hierarchical modelling can be applied to measure the variation in and the relationship between child undernutrition and individual, maternal, household and community-level covariates integrated at different levels. The findings from the present study offer useful insights for policymakers to understand the complex interplay between individual, household and community factors on child undernutrition outcomes in Sri Lanka.

7.5 Policy implications and recommendations

The Ministry of Health in Sri Lanka has implemented several strategies to reduce low birth weight. One such example is the National Nutrition Policy (NNP) revised in 2010 along with the National Nutrition Strategy. The main objective of the NNP was to ensure adequate nutrition for everyone irrespective of their geographical location and socioeconomic status (Ministry of Healthcare and Nutrition, 2010).

However, the first analysis demonstrated evidence that the progress on the reduction of low birth weight has been slow, even though the NNP aimed to ensure adequate nutrition for all pregnant mothers to enable the delivery of a healthy baby with an adequate weight (Rajapaksa et al., 2011). There was clear evidence of social and economic inequalities in child undernutrition outcomes including low birth weight. Most of the negative nutrition outcomes are concentrated in poor households, especially in the estate sector (World Health Organization, 2017a). For instance, mothers in Sabaragamuwa Province, which is predominantly a tea plantation area, and consists mostly of rural and estate sectors are particularly vulnerable to having low birth weight children (Department of Census & Statistics, 2012). Therefore, the present findings suggest that there is a need to prepare estate-specific nutritional interventions that cover their unmet needs, highlight their implementation and coverage gaps. Present programmes, especially maternity packages, seem unfavourable to estate mothers compared to mothers in other sectors. They should be regularly monitored using feedback from all those involved (Jayawardena, 2014; World Health Organization, 2017a). This study reinforces the National Nutrition Policy recommendation for exclusive targeting of “underserved areas, plantation community, urban poor and areas”, as identified by the nutrition surveillance system (Ministry of Healthcare and Nutrition, 2010, p. 10).

The gap in child and maternal undernutrition between the rich and poor group calls for a closer examination of some of the existing poverty reduction and health programmes. For example, Samurdhi, one of the country’s main comprehensive cash-transfer programmes on poverty reduction, introduced in 1995, provides an income supplement of between 500-1,000 rupees depending on family size and household poverty level (Glinskaya, 2016). However, it appears that Samurdhi has not been fully effective in reaching out to poor families, especially in the estate sector who are the key beneficiaries. The present study highlights the need for greater efforts to prioritise the target group and key beneficiaries depending on household poverty levels. It is also essential to expand the funds, so beneficiaries receive the full package of essential interventions.

Although Sri Lanka has adopted the WHO standard cut-off (less than 2500 grams) to measure the low birth weight prevalence, the appropriateness of using WHO Multicentre Growth Reference was questionable, as surveys reported that the mean birth weight in Sri Lanka was significantly lower than the WHO standard (Abeyagunawardena et al., 2018; Perera et al., 2013). In agreement with previous studies mentioned, the present study also suggests the development of a country-specific standard to assess birth outcomes, including low birth weight.

The existing findings also highlight the influential role of maternal factors in determining low birth weight. Hence, any intervention should focus on improving the nutritional status (height and BMI) of mothers. This should be achieved through educating on optimal birth weight and BMI to adolescent girls at school age and women in reproductive ages. Moreover, proper anthropometric screening for pre-pregnant women at antenatal clinics should be implemented.

Sri Lankan mothers receive more comprehensive antenatal, intrapartum and postnatal care for new mothers than do mothers in other South Asian countries under the Maternal and Child Health (MCH) programmes, carried out by the Family Health Bureau (FHB). The present study found that the mean number of antenatal visits was six, nevertheless, WHO has recommended having a minimum of eight visits to reduce perinatal mortality and improve women's experience of care (World Health Organization, 2016). Therefore, it is essential to identify spatial, financial and cultural barriers to accessing to antenatal and postnatal care services, particularly targeting mothers from economically deprived communities (such as those in the estate sector). Also, it is suggested that awareness and coverage of iron and folic acid supplementation during pregnancy be raised as an effective way to reduce the risk of low birth weight outcomes. As reported elsewhere, MCH programme accounted for only 5% of the total nutrition-specific funding from the government (Institute of Policy Studies, 2020), which should deserve more investment in terms of allocating more resources to combat malnutrition.

The findings of the present study suggest that the government's existing free food supplementation of two packets of Thriposha per month was not significantly associated with nutritional outcomes. The effectiveness of the "Thriposha" has been questionable in preventing acute malnutrition, in terms of inadequacy in production and distribution, limited coverage and challenges in delivering to the target population (actual recipients). As reported elsewhere, pregnant women and low birth weight children living in the government estates are less likely to receive Thriposha on a regular basis compared to women living in other sectors (World Health Organization, 2017a). Hence, it is essential to identify the causes of supply disruptions and to increase the coverage for pregnant mothers and children. Also, the present study highlights the need for ascertaining the effect of Thriposha on birth outcomes, especially compliance and actual consumption during the early stages of pregnancy. Thriposha fulfils only 400 kcal of energy needs (Sri Lanka Thriposha Limited, 2016) which is inadequate for undernourished mothers (Rannan-Eliya, 2015). Hence, a balanced energy and protein supplementation during pregnancy that covers more than 700 kcal per day for pregnant women could be considered in nutritional intervention programmes especially targeting thin or underweight women. It has been reported that the country's annual public investment in key nutrition-specific interventions is approximately around Rs. 15 billion. Of these investment, Thriposha programme accounted for 16 per cent (Institute of Policy Studies, 2020). However, the effectiveness of the Thripsoha programme raised a concern on rebalancing the annual public investments towards better targeted, evidence-based nutrition interventions.

In addition, the efficiency of other programmes such as "*Poshana Malla*" (bag of nutrients) introduced in 2015 by the Ministry of Health for pregnant mothers and the "free mid-day Meal" for school children, should be revisited. Availability of junk food in school canteens found as a limitation for the nutrition of school children where proper monitoring guidelines of school canteens should be required to overcome this situation (Higashi et al., 2020). We need more recent data to properly disentangle the effect of *Poshana Malla*. The staple food fortification, which is one of the relevant existing nutrition strategies in Sri Lanka could be expanded by introducing varieties of fortified food including rice/wheat flour with vitamins and minerals for young children aged 6-23 months (Jayawardena, 2020).

The second analysis found that low birth weight (LBW) children are at a substantially increased likelihood of being stunted, wasted or underweight. In addition, the findings suggest a possible intergenerational transmission of malnutrition, where mothers with poor nutritional stature have an increased risk of having low birth weight babies who then potentially become undernourished children. This could be identified as one of the crucial factors for the stalled child undernutrition outcomes in Sri Lanka, especially among poor people. Hence considerable attention should be given to ensuring health and nutrition of adolescents' girls/women before and during pregnancy when implementing nutritional policies.

The results also clarified the role of maternal education in affecting child undernutrition outcomes. Maternal education is recognised as a proxy for socioeconomic status: less educated mothers tend to be in the lower socioeconomic groups and are more prone to have low birth weight and underweight children. Educated mothers can make better decisions on the quality and quantity of food, and they have better family health awareness and hygiene and feeding practices. Therefore, further investment in improving maternal education and awareness about healthy pregnancies is needed to tackle the undernutrition of both mothers and children.

Infant and young feeding practices (IYCF) in Sri Lanka are much superior to those of other South Asian countries (Agampodi et al., 2009; World Health Organization, 2017a), however, they do not appear to have a strong impact on the stagnant nutrition indicators. There are variations in the types of food consumed by mothers and children. Among children who are aged 6-23 months, lower consumption rates reported for animal protein include eggs, dairy products. The lowest levels of intake of animal proteins could be potentially linked with food insecurity, dietary issues, social and cultural beliefs on foods and knowledge gaps, which should be given attention. The relatively poor IYCF indicators in the estate sector are also another matter of concern, hence estate sector-specific barriers such as lack of affordability and access to food should be properly identified and addressed (Senarath et al., 2012). In addition, prolonged breastfeeding for children aged 24 to 36 months is associated with child stunting, wasting and underweight, therefore relevant approaches should be taken to educate mothers on appropriate breastfeeding practices and initiation of optimal complementary feeding practices (Syeda et al., 2020). Further research is needed to investigate the effect of breastfeeding duration on maternal health and nutritional status in the context of Sri Lanka.

In the analysis in Chapter 6, on DBM at the household level, findings suggest that despite satisfactory performance in other health indicators, Sri Lanka is facing a DBM challenge of reducing both child undernutrition and maternal overweight and obesity within the household. Sri Lanka is already at a development stage characterised by rapid economic growth and a shift towards an industrial economy. Nevertheless, child undernutrition is still a problem. Because of the shift away from an agrarian economy, we can expect that chronic nutrition-related diseases associated with changes in dietary patterns and less physical activity will tend to increase. There is scope, therefore, for an increase in the DBM. Policies and actions taken so far to combat malnutrition have not involved simultaneous actions tackling both ends of malnutrition. The findings of the present study call for the early detection of undernutrition and overnutrition in order to prevent long-term nutritional challenges and associated disease burdens. Chapter 6 also reflects the strong link between DBM and the Muslim ethnicity. The changes in dietary patterns among child-mother pairs in the same households also reflected in this chapter. Although the recall bias in dietary data (24-h recalls), could be identified as a limitation in this study, public health initiatives such as nutrition counselling on IYCF practices and healthy eating behaviours at the school level or community level are important. For example, a pregnant or lactating mother who is being overweight or obese could receive nutritional advice from the antenatal care (ANC) and postnatal care (PNC) platforms. The Sri Lanka government has recently (2020) implemented a “Traffic light colour coding system”, in which sugary products should display colour codes according to their sugar content. However, this was only introduced for a limited range of food categories, and it could be expanded to other foods with the aim of lowering the risk of overweightness and NCDs. Also, further research is needed to explore the biological, socioeconomic pathways linking diet and DBM, disaggregating the analysis by residential sectors, provinces and ethnicity, particularly among Muslims who are experiencing escalation rates of overweight and obesity. This study further confirms that the causes of DBM at the household level are multifaceted. This should inform policy interventions, which need to combine various measures such as proper infant and young child feeding using high-quality complementary foods to promote growth and development, provide adequate micronutrients to avoid excessive weight gain after two years and improve households’ access to healthy cheap food (Black and Sesikeran, 2018).

The interrelated papers provide evidence on the life cycle effect of malnutrition. For instance, mother’s poor nutritional status during pregnancy exacerbates to have a poor birth outcome such as low birth babies, being born underweight leads to growth retardation in childhood which then causes nutritional challenges in adulthood, thus the cycle of malnutrition continues. Overall, the findings of this thesis call for a concerted and comprehensive nutritional programme to address all types of malnutrition throughout an individual's life course.

7.6 Limitations and recommendations for future research

The strengths and limitations of the data are explained in each respective analysis, thus this section will summarize the general limitations of the thesis and put forward suggestions for future work. The quantitative research design of the thesis could be generalizable to a broader context. Also, the data used in the thesis permitted population-level analysis using first nationally representative data that covered the whole island after the civil war ended in 2009.

However, the quantitative nature of the analysis means that causality could not be inferred and the underlying reasons for preferences made by respondents could not be obtained without relevant qualitative research. Therefore, this study could benefit from additional qualitative research to obtain a more comprehensive understanding of child undernutrition and DBM at the household level. Despite the inconsistency of using the standard MEASURE DHS format, analysis using the DHSs could be expanded to include other countries within South Asia that would enables the cross-country data comparison of countries.

Although this study used various factors in order to identify child undernutrition and DBM, malnutrition is a complex phenomenon that could be affected by various factors, therefore it would be better to use additional in-depth population and individual-level factors of household malnutrition. Hence, future work would also benefit from using longitudinal research methods to identify the effect of behavioural determinants including dietary intake, physical activity, caregiving practices, community and cultural determinants and genetic factors on child malnutrition.

Lastly, we need to undertake rigorous methodological studies to assess whether the WHO standard cut-offs are appropriate to interpret child and maternal low birth weight and anthropometric measures in Sri Lanka. Finally, it will be beneficial for future research to investigate specific biomarkers to better understand, inform and guide nutritional interventions in Sri Lanka.

Appendix A Published paper

Open access Original research

BMJ Open

Social inequalities in low birthweight outcomes in Sri Lanka: evidence from the Demographic and Health Survey 2016

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ABSTRACT

Objective To investigate social inequalities underlying low birthweight (LBW) outcomes in Sri Lanka.
Design Cross-sectional study.
Setting This study used the Sri Lanka Demographic and Health Survey 2016, the first such survey to cover the entire country since the Civil War ended in 2009.
Participants Birthweight data extracted from the child health development records available for 7713 babies born between January 2011 and the date of interview in 2016.
Outcome measures The main outcome variable was birth weight, classified as LBW (≤2500 g) and normal.
Methods We applied random intercept three- level logistic regression to examine the association between LBW and maternal, socioeconomic and geographic variables. Concentration indices were estimated for different population subgroups.
Results The population-level prevalence of LBW was 16.9% but was significantly higher in the estate sector (28.4%) compared with rural (16.6%) and urban (13.6%) areas. Negative concentration indices suggest a relatively higher concentration of LBW in poor households in rural areas and the estate sector. Results from fixed effects logistic regression models confirmed our hypothesis of significantly higher risk of LBW outcomes across poorer households and Indian Tamil communities (AOR 1.70, 95% CI 1.02 to 2.83, $p<0.05$). Results from random intercept models confirmed there was substantial unobserved variation in LBW outcomes at the mother level. The effect of maternal biological variables was larger than that of socioeconomic factors.
Conclusion LBW rates are significantly higher among babies born in poorer households and Indian Tamil communities. The findings highlight the need for nutrition interventions targeting pregnant women of Indian Tamil ethnicity and those living in economically deprived households.

Strengths and limitations of this study

- ▶ The survey covered the entire island for the first time after the Civil War ended in 2009.
- ▶ Birthweight data were obtained from child health records, and most of the births are institutional deliveries.
- ▶ Birthweight data can be biased due to rounding errors or other errors related to weighing instruments.
- ▶ Due to data constraints, data on genetic factors and prepregnancy weight that could have affected the low birth weight were not included in the analysis.

INTRODUCTION

Over the last few decades, Sri Lanka has experienced a marked reduction in infant, child and maternal mortality rates,[1 2] when compared with other South Asian countries. However, there has been little or no progress in child health indicators in Sri Lanka particularly low birthweight (LBW) outcomes, which have hindered the achievement of health-related United Nations Millennium Development Goals.[3] For example, despite the reduction of LBW rates from 22.8% to 16.7% between 1990 and 2000, the percentage of children born with LBW has remained at around 17% since 2000 (figure 1).[1–4]

LBW is a critical factor associated with neonatal and infant deaths, and nutritional and health outcomes at later stages of child development.[4–9] LBW babies are more vulnerable to contracting infections, malnutrition and disability during childhood than those born with normal weight, particularly cognitive disorders related to behaviour and learning.[5] LBW babies who survive infancy are also vulnerable to increased risks of non-communicable and chronic diseases in adulthood.[9 10]

Global and regional variations in LBW rates are pronounced, with the highest burden in low-income and middle-income countries, which account for more than 95% of all LBW babies. South Asia has the largest share of LBW babies, constituting 48% of all LBW babies globally[4 11] with the highest rates recorded in Bangladesh, India and Pakistan.[12] Maternal biobehavioural risk factors such as age, nutritional status, poor diet during pregnancy, body mass index (BMI), gestational

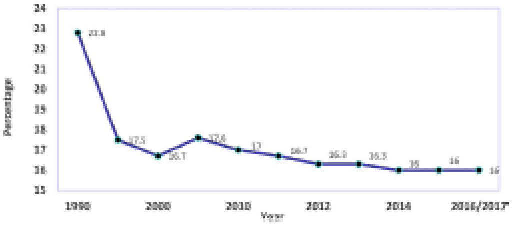

Figure 1 Percentage of babies with low birth weight in Sri Lanka: 1990–2017. Data source: Department of Census and Statistics.[1]

age, interpregnancy interval, parity and lack of antenatal care as well as social, economic and environmental factors such as poverty and low socioeconomic status are associated with LBW outcomes globally.[4 11–15]

High rates of LBW remain a critical public health problem in Sri Lanka, with a long-term impact on health outcomes, disease burden and economic productivity.[16] Despite a plethora of national health programmes, including a programme promoting universal access to antenatal care, a multisectoral food and micronutrient supplementation programme aligned to the National Nutrition Policy (2009–2013) and poverty alleviation programmes, there has been little reduction in the incidence of LBW outcomes.[17] Previous small-scale community studies in Sri Lanka have identified that the risk of LBW babies is particularly high among mothers in the estate sector.[17–20] The estate sector comprises mostly Indian Tamil tea plantation workers who live in the centre and south of Sri Lanka.[21]

Existing studies on LBW have been focused on homogeneous and relatively small samples in specific settings, for example, rural or hospital-based studies. There is little population-level research on the extent of inequalities in LBW outcome in Sri Lanka. The present research addresses this gap by analysing the social inequalities underlying LBW outcomes and associated risk factors in Sri Lanka, based on recent data from a nationally representative cross-sectional survey. We hypothesise that children born in poor households and to the Indian Tamil tea plantation workers in the estate sector are more vulnerable to LBW outcomes than their counterparts living in richer households in other rural areas and in towns and cities.

METHODS

Sample

We used data from the Sri Lanka Demographic and Health Survey (SLDHS) conducted during 2016–2017. This is the first nationally representative sample survey to be implemented since the Civil War ended in 2009. The SLDHS used a two-stage stratified sampling design. A total of 28 800 housing units were selected for the survey. Within the households, 18 302 married women aged 15–49 years were selected for interview. SLDHS collected detailed data on birth histories and mothers' reproductive health behaviours, along with socioeconomic and demographic data.

The analysis considered 7072 mothers of reproductive age (15–49 years) who had at least one birth in the 5 years preceding the survey: 6069 had one birth, and 1003 had two or more births, of whom 27 had three children and 1 had four children. The total number of births to the 7072 mothers was 8104. Of these, 7964 were singleton (98.3%) and 140 (1.7%) were multiple births. For 251 singleton births, either the birthweight data were missing or the reported birth weight was extreme (over 6500 g (0.36% of births)).

For the remaining 7713 births, the mean birth weight was 2917 grams (95% CI 2906 to 2927), and the median was 2920 g. For 140 multiple births, the mean birth weight was 2135 g (95% CI 2050 to 2214) and the median was 2175 g. We excluded multiple births in the further analysis, since 81% of the multiple births had LBW. We found no statistical difference in the distribution of socioeconomic factors between singleton and multiple births. For 220 cases (2.6% of the total), birth weight was recorded at exactly 2500 g. Our final analysis sample includes 7713 singleton births with a recorded birth weight between January 2011 and November 2016 (survey date).

Outcome variable

We followed the standard definition of LBW (babies weighing less than 2500 g) and also considered those with a reported birth weight of exactly 2500 g[22] to allow for potential rounding errors while entering LBW data on child health development records.

Explanatory variables

We grouped the explanatory variables into three categories: maternal depletion, socioeconomic and geographical. The classification of maternal depletion variables was on the basis of the theory of maternal depletion syndrome that states that women with closely spaced pregnancies are vulnerable to enter the reproductive cycle with reduced nutrition reserves.[23] Maternal nutrition depletion may lead to negative outcomes such as LBW, infant mortality and reduced fecundity.[23–25] SLDHS has limited variables to measure maternal depletion: maternal age, maternal BMI and height, preceding birth interval, micronutrient (iron and folic acid tablets) intake and food supplementation (*Thriposha*) received during pregnancy. Micronutrient supplementation and *Thriposha* are recommended by the government and are given free for pregnant and lactating mothers in Sri Lanka.[17] We also have data on the frequency of antenatal care visits and the sex of the child. The survey asked mothers to report their gestational age in months. However, we did not use this information since the reported gestational data (in months) could be biased and grossly underestimated.

In addition, we considered the following socioeconomic variables: maternal education, a household wealth index as a proxy for measuring socioeconomic status and ethnicity.

Household wealth index quintile is a standard composite measure of household ownership of assets, materials and access to basic sanitation. The DHS estimates household wealth index using principal component analysis separately for urban, rural and sector areas. Finally, we considered two key geographic variables: (1) place of residence classified as urban, rural and estate sector (the urban sector is composed of areas administered by municipal and urban councils, the estate sector is predominantly concentrated in the tea plantation areas, while the rural sector comprises the areas not captured by the urban and estate sectors)[1] and (2) nine administratively defined provinces.

Statistical analysis

We examined the binary association between birth weight and selected characteristics. The outcome variable is coded 0 (reference) for babies with a normal weight and 1 for those weighing 2500 g or less. Then we fit a series of binary logistic regression models. Model 1 includes maternal depletion variables, model 2 includes maternal depletion and socioeconomic variables and model 3 includes maternal depletion, socioeconomic variables and geographical variables. The variance inflation factor is used to check for collinearity and to ensure that the assumptions of multicollinearity are not violated. Due to the hierarchical nature of the data with some mothers having more than one child (903 mothers), and these mothers being grouped within communities (primary sampling units or clusters), we examine the variation in LBW at three levels: child, mother and community, using the same series of models, but taking account of the fact that some mothers have more than one child, and mothers are clustered within communities.

Additionally, we estimated concentration indices to measure the extent of wealth inequalities underlying LBW, which are illustrated graphically using concentration curves.

Patient and public involvement

Not applicable for this study

RESULTS

Descriptive analysis

Table 1 shows the statistical association between birth weight and selected variables. About 17% of babies were born with a LBW, and the rate was significantly higher among babies born in the estate sector (28.4%) when compared with rural (16.6%) and urban (13.6) areas. LBW was concentrated among teenage and young mothers aged under 20 and 20–24 years. There is a positive association between maternal anthropometric measures (BMI and height) and LBW. The association between LBW and the number of antenatal visits is marginal (table 1). There was no significant association between LBW and receipt of *Thriposha* during pregnancy. However, LBW was relatively common among mothers who had not had iron and folic acid supplements. Female babies were more likely than male babies to be born with LBW. Among the socioeconomic characteristics, the prevalence of LBW was inversely related to educational attainment and household wealth. For example, 21.4% of mothers in the lowest wealth quintile had LBW babies, compared with only around half that proportion among the highest wealth quintile. Indian Tamils were more likely than the other ethnic groups to have LBW babies, and mothers living in the estate sector generally have a higher proportion of LBW babies (28.4%) compared with their counterparts living in rural and urban areas. LBW was common in Central and Sabaragamuwa regions and less common in the Northern region (table 1).

The socioeconomic differentials are further illustrated in the concentration curves (figure 2A,B). A concentration index ranges in value between −1 and +1. Negative values indicate that the variable is concentrated in poor households, a value of zero indicates there is no inequality and positive values indicate that the variable is concentrated in the richest households. The concentration curve is a graphical exploration of the concentration index. If the concentration curve lies on the diagonal 45° line, it shows perfect equality; when it lies below the line, the outcome is more concentrated among the higher SES (socioeconomic status) individuals of the population; if it lies above the 45° line, the outcome is more concentrated among the poor SES individuals in the population.[26]

The results for LBW show a concentration index of −0.13 (95% CI −0.15 to 0.10), suggesting that LBW is concentrated among the poorer households (figure 2A). The curve shows that, for example, the poorest 20% of households have about 30% of LBW babies, whereas the richest 20% of households have only about 10% of LBW babies. We graphed concentration curves by residential sector (figure 2B). The concentration curves for all sectors lie above the equality line, which suggests that LBW outcomes were higher among children in poorer households. The results show that that inequality within each sector is less than overall inequality and that, in particular, there is equality of LBW outcomes within the estate sector. This may be because the estate sector consists very largely of poor households.

Regression analysis

Table 2 shows the results of fixed effects logistic regression models with LBW as the outcome. In model 1, we included only maternal depletion variables. Mothers with a low BMI were more likely to have an LBW baby than those with normal BMI levels (adjusted OR (AOR) 1.76, 95% CI 1.41 to 2.20). There is a strong inverse association between maternal height and LBW outcome. Mothers who did not consume iron or folic acid (AOR 1.48, 95% CI 1.02 to 2.14) and those with a female birth (AOR 1.39, 95% CI 1.19 to 1.63) were more likely to have an LBW baby than those who did not consume iron or folic

Table 1 Percentage distribution of recorded birth weight by maternal depletion, socioeconomic and geographical factors: Sri Lanka, 2016

Variable and category	Birth weight (in grams) ≤2500	2501–3000	3001–3500	3501–6500	Number of births	P value
All data	**16.9**	**38.0**	**34.9**	**10.2**	**7,713**	
Maternal age (years)						
Under 20	25.6	39.1	31.0	4.0	74	0.001
20–24	19.7	41.9	31.2	7.1	1,012	
25–34	16.1	37.8	35.9	10.0	4,468	
35–39	16.2	36.1	34.2	13.2	1,622	
40 and over	18.4	36.5	35.3	9.6	537	
Maternal body mass index						
Under 18.5	26.4	45.5	24.4	3.5	847	0.000
18.5–24.9	17.2	39.9	33.9	8.8	3,726	
25.0–29.9	14.1	33.9	38.4	13.5	2,171	
30.0 or more	11.8	31.9	40.1	15.9	801	
Maternal height						
Short (up to 145.0 cm)	28.8	41.2	24.5	5.3	545	0.000
Average (145.1–155.0 cm)	18.5	39.6	32.9	8.7	4,198	
Tall (155.1 cm and over)	12.0	34.8	39.5	13.5	2,821	
Preceding birth interval						
First birth	19.5	40.6	32.0	7.7	3,011	0.000
Under 24 months	14.9	34.5	36.5	13.9	394	
24–47 months	12.7	35.5	39.1	12.5	1,594	
48–59 months	15.2	35.3	36.4	12.9	793	
60 months or more	17.3	37.5	34.8	10.3	1,931	
Received Thriposha						
Received and consumed	18.5	43.8	30.5	7.3	504	0.108
Received and shared	17.0	37.5	34.8	10.5	5,921	
Not received	9.7	40.7	37.8	11.6	103	
Taken iron and folic acid supplements						
Received and consumed	16.5	38.1	35.0	10.3	6,503	0.000
Not received and consumed	25.7	36.0	26.6	11.5	1,210	
Antenatal care visits						
Fewer than three times	16.9	38.2	35.7	9.0	1,378	0.041
3–5 times	24.0	37.1	30.6	8.1	737	
6–10 times	16.1	38.1	35.0	10.6	5,314	

Continued

Table 1 Continued

Variable and category	Birth weight (in grams) ≤2500	2501–3000	3001–3500	3501–6500	Number of births	P value
11 or more times	12.3	36.2	38.3	13.0	284	
Sex of child						
Male	15.1	37.4	36.3	11.3	4,000	0.000
Female	18.7	38.8	33.5	9.0	3,794	
Education level						
No education and primary	27.6	40.2	24.7	7.3	380	0.000
Secondary and passed General Certificate of Education (GCE) O-level	18.0	38.4	33.7	9.7	5,127	
Passed GCE A-level	11.6	39.0	38.0	11.2	1,761	
Degree and above	15.0	26.2	44.7	13.9	445	
Wealth index quintile						
Poorest	21.4	40.6	29.8	8.0	1,900	0.000
Poor	17.8	38.0	35.3	8.7	1,571	
Middle	17.9	38.5	33.2	10.2	1,460	
Rich	14.1	36.5	37.8	11.4	1.514	
Richest	10.8	34.9	40.3	13.8	1,268	
Ethnicity						
Sinhala	17.2	38.0	34.5	10.0	5,025	0.000
Sri Lanka Tamil	15.9	36.4	36.8	10.8	1,564	
Indian Tamil	32.6	42.5	23.5	1.2	242	
Muslim	12.1	38.6	36.7	12.4	857	
Burgher and Malay	12.0	48.0	28.0	12.0	25	
Residential sector						
Urban	13.6	34.4	38.5	13.2	1,249	0.000
Rural	16.6	38.1	35.2	10.0	5,972	
Estate	28.4	45.1	21.9	4.4	492	
Province						
Western	14.5	37.8	36.5	11.1	1,455	0.000
Central	20.2	38.8	32.7	8.3	996	
Southern	16.4	38.1	34.3	11.0	923	
Northern	12.0	34.4	40.3	13.1	905	
Eastern	17.0	37.5	35.0	10.3	857	
North-Western	17.1	34.9	35.7	12.1	832	
North Central	14.3	42.4	33.2	10.0	530	
Uva	18.7	41.0	35.1	4.9	543	
Sabaragamuwa	24.1	39.7	27.9	8.1	672	

Data source: Sri Lanka Demographic and Health Survey 2016.
*P<0.05; **p<0.01; ***p<0.001.

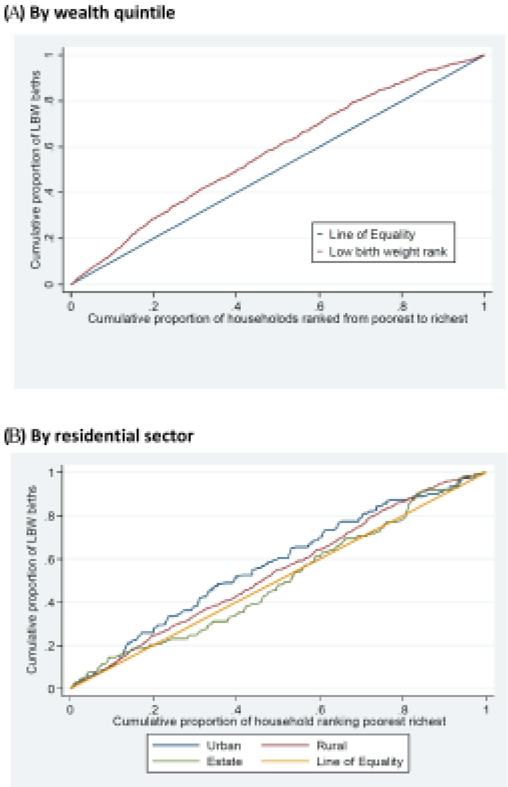

Figure 2 (A) Concentration curve showing the cumulative proportion of low birth weight (LBW) by wealth quintiles. (B) Concentration curves showing the cumulative proportion of LBW by residential sector.

acid or who has a male baby, respectively. Babies born 24–47 months after their immediately elder sibling were at lower risk of having LBW compared with the first-born child (AOR 0.58, 95% CI 0.46 to 0.73).

Model 2 added socioeconomic variables. Although the ORs for the maternal depletion variables in models 1 and 2 cannot properly be compared because it is problematic to compare ORs across models with different independent variables in the sample as it reflects the degree of unobserved heterogeneity in the model, there was little or no change in the effect of the maternal depletion variables (table 2). Household wealth was a strong predictor of LBW outcome: babies born in the highest household wealth quintile had half the odds of LBW compared with those in the lowest quintile (AOR 0.50, 95% CI 0.36 to 0.69). Maternal education level was less important, although mothers with higher levels of education tended to have reduced odds of a LBW baby. There were some differences by ethnicity: Burgher and Malay mothers were less likely to have LBW babies, whereas the Indian Tamils were more likely to have LBW outcomes compared with Sinhala mothers (AOR 1.48, 95% CI 1.03 to 2.13).

The final model included the geographical variables residential sector and province in addition to maternal and socioeconomic factors (table 2). We removed the iron and folic acid variable from the model, as it was no longer significant in model 2 (though we note that mothers who had not received and consumed iron and folic acid had a higher risk of LBW babies than mothers who had received and consumed both these supplements). Both maternal and socioeconomic factors remain important predictors of LBW; however, residential sector was less important. The effect of Indian Tamil ethnicity remained significant with a higher odds (AOR 1.70, 95% CI 1.02 to 2.83). Similarly, mothers who lived in Sabaragamuwa province had higher odds of LBW than those from the Western province (AOR 1.42, 95% CI 1.07 to 1.87). LBW babies were more common among Indian Tamils than among other ethnic groups. The Indian Tamils lived and worked mostly at tea plantation estates in Sabaragamuwa province.

Random effects

Our data are hierarchical, in that some quantities are specific to children, whereas others are defined and measured at the mother level and yet others, such as provinces, are defined at a broader community level. It might be that characteristics of mothers and/or communities lead to the risk of LBW among children born to the same mother, or born within the same community, being correlated. Some of these characteristics can be observed (eg, mother's BMI) but others (eg, genetic factors) cannot be observed. To assess the magnitude of these correlation effects, we estimated a model of LBW with no covariates but three variance parameters at the child level, the mother level and the community level. We found very little correlation between the risk of LBW for babies within the same community but substantial correlation between the risk of LBW for children of the same mother. More than 60% of the variance in LBW is the result of variation between mothers. This suggests that any community-level effects were those deriving from the characteristics of mothers living in the same community.

To take account of this mother-level variation, we re-estimated model 3 described previously adding a random effect at the mother level. The results are shown in table 3. The effect of the covariates is similar to that in the comparable fixed effects model, though in some cases (eg, maternal height) their impact is amplified.

DISCUSSION

Our findings confirm the research hypothesis of a clear socioeconomic gradient in the risk of LBW in Sri Lanka. Mothers from poor households, especially those from Indian Tamil communities living in the estate sector, have increased risk of LBW babies. The persistence of LBW among this group might be attributed to genetic factors

Table 2 Results of the fixed effects multiple logistic regression

Variable and category	Model 1 Adjusted OR (95% CI)	Model 2 Adjusted OR (95% CI)	Model 3 Adjusted OR (95% CI)
Maternal body mass index			
Under 18.5	1.76 (1.41 to 2.20)***	1.62 (1.29 to 2.03)***	1.63 (1.31 to 2.03)***
18.5–24.9	Ref	Ref	Ref
25.0–29.9	0.78 (0.65 to 0.95)*	0.83 (0.69 to 1.00)	0.85 (0.71 to 1.03)
30.0 or more	0.73 (0.55 to 0.96)*	0.80 (0.60 to 1.06)	0.74 (0.56 to 0.98)*
Maternal height			
Short (up to 145.0 cm)	1.91 (1.47 to 2.74)***	1.76 (1.36 to 2.29)***	1.74 (1.35 to 2.24)***
Average (145.1–155.0 cm)	Ref	Ref	Ref
Tall (155.1 cm and over)	0.55 (0.46 to 0.66)***	0.58 (0.49 to 0.70)	0.58 (0.49 to 0.69)***
Preceding birth interval			
First birth	Ref	Ref	Ref
Under 24 months	0.68 (0.47 to 0.98)*	0.67 (0.46 to 0.96)*	0.73 (0.52 to 1.04)
24–47 months	0.58 (0.46 to 0.73)***	0.56 (0.44 to 0.70)***	0.59 (0.48 to 0.73)***
48–59 months	0.77 (0.59 to 1.08)	0.73 (0.56 to 0.96)*	0.77 (0.59 to 0.99)*
60 months or more	0.92 (0.76 to 1.18)	0.85 (0.70 to 1.04)	0.87 (0.72 to 1.05)
Taken iron and folic acid supplements			
Received and consumed	Ref	Ref	
Not received and consumed	1.48 (1.02 to 2.14)*	1.43 (0.98 to 2.08)	
Antenatal care visits			
Fewer than three times	1.30 (0.79 to 2.15)	1.43 (0.86 to 2.37)	1.25 (0.81 to 1.93)
3–5 times	1.73 (1.09 to 2.73)*	1.78 (1.11 to 2.85)*	1.75 (1.09 to 2.81)*
6–10 times	1.13 (0.75 to 1.70)	1.14 (0.75 to 1.72)	1.15 (0.76 to 1.74)
11 or more times	Ref	Ref	Ref
Sex of child			
Male	Ref	Ref	Ref
Female	1.39 (1.19 to 1.63)***	1.40 (1.20 to 1.64)***	1.45 (0.16 to 1.67)***
Education level			
No education and primary		Ref	Ref
Secondary and passed General Certificate of Education (GCE) O-level		0.75 (0.55 to 1.03)	0.80 (0.58 to 1.10)
Passed GCE A-level		0.58 (0.40 to 0.84)**	0.63 (0.44 to 0.90)*
Degree and above		0.90 (0.57 to 1.44)	0.92 (0.58 to 1.46)
Wealth index quintile			
Poorest		Ref	Ref
Poor		0.82 (0.65 to 1.04)	0.82 (0.65 to 1.03)
Middle		0.81 (0.64 to 1.02)	0.84 (0.66 to 1.07)
Rich		0.73 (0.56 to 0.94)*	0.74 (0.58 to 0.96)*
Richest		0.50 (0.36 to 0.69)***	0.54 (0.40 to 0.73)***
Ethnicity			
Sinhala		Ref	Ref
Sri Lankan Tamil		0.85 (0.68 to 1.05)	1.03 (0.74 to 1.43)
Indian Tamil		1.48 (1.03 to 2.13)*	1.70 (1.02 to 2.83)*
Muslims		0.82 (0.61 to 1.11)	0.86 (0.63 to 1.18)
Burgher and Malay		0.54 (0.16 to 1.77)	0.43 (0.13 to 1.45)

Continued

Table 2 Continued

Variable and category	Model 1 Adjusted OR (95% CI)	Model 2 Adjusted OR (95% CI)	Model 3 Adjusted OR (95% CI)
Residential sector			
Urban			Ref
Rural			0.97 (0.77 to 1.23)
Estate			1.06 (0.66 to 1.68)
Province			
Western			Ref
Central			0.99 (0.74 to 1.32)
Southern			1.05 (0.78 to 1.41)
Northern			0.60 (0.38 to 0.94)*
Eastern			1.06 (0.76 to 1.47)
North-Western			1.16 (0.89 to 1.51)
North Central			0.93 (0.64 to 1.24)
Uva			0.89 (0.63 to 1.24)
Sabaragamuwa			1.42 (1.07 to 1.87)*

***P<0.001; **p<0.01; *p<0.05; Ref: reference category.

deriving from the selected group of marginalised communities of Indian Tamils who were originally brought to Sri Lanka to work in the tea plantations in the 19th century.[20] There is a lack of research on genetic causes of LBW in Sri Lanka, and a more thorough investigation of the genetic factors associated with LBW is needed.

The foregoing analyses of SLDHS data confirms the prominent role of maternal factors in determining LBW outcomes. Maternal depletion factors such as maternal BMI and height and preceding birth interval were more influential in determining LBW than socioeconomic and geographical factors. Multilevel analysis revealed that more than 60% of the variation in LBW occurred at the maternal level. Once this had been accounted for, there was very little additional variation (6% of the total) at the community level. Birth weights of children born to the same mother were highly correlated, partly reflecting the impact of unmeasured factors such as genetic and environmental factors that were not taken into account in the fixed effect model.

Our findings highlight the need for nutrition interventions targeting pregnant women from the Indian Tamil ethnicity and those living in economically deprived households. The government in Sri Lanka has taken several measures to improve the nutritional status of pregnant mothers, particularly the free distribution of *Thriposha* targeted at poor families. However, the effect of receiving and consuming *Thriposha* was not significant, consistent with findings from previous research.[20] This might be due to the fact that *Thriposha* fulfils only 400 kcal of energy needs,[27] which is not adequate for undernourished mothers[28] or our inability to identify true recipients of it. The present study suggests revisiting the effectiveness of *Thriposha* programme in addressing the nutritional needs of mothers. The other existing poverty alleviation programme in Sri Lanka is *Samurdhi* (prosperity), which was launched in 1994. This also only provides a modest quantity of monetary support (only 500–1000 rupees) (around US$2.75–5.5) and does not always target the right beneficiaries.[29 30]

This study showed that increasing the frequency of antenatal care visits tends to reduce the risk of LBW outcome. Antenatal clinics provide comprehensive health promotion and pregnancy care services for mothers, such as dietary advice including micronutrient and *Thriposha* supplementation, methods of newborn care, monitoring of the fetus, examination of maternal biomarkers and haemoglobin.[15–17] Therefore, it is vital to expand the services and coverage targeting vulnerable women settled in the estate sector.

LBW is concentrated among poor people, especially within the estate sector. Hence, to be more effective in reducing the prevalence of LBW, the *Samurdhi* programme should be expanded to target the poorest mothers in the estate sector. Since the maternal level is more influential in determining LBW in the context of Sri Lanka, policies should be more centred on improving maternal factors including nutritional level.

Strengths and limitations of this study

The present research is based on cross-sectional data at the national level, which has been collected for the first time after the war and civil conflict in Sri Lanka. The analysis is based on data from health records, which are fairly accurate in Sri Lanka where institutional birth is universal. However, previous studies show that birth weight data may be biased due to rounding errors or other errors related to weighing instruments even in

Table 3 Results of the two-level random intercept logistic regression model

Variable and category	Adjusted OR (95% CI)
Maternal body mass index	
Under 18.5	2.14 (1.48 to 3.09)***
18.5–24.9	Ref
25.0–29.9	0.71 (0.54 to 0.94)*
30.0 or more	0.60 (0.39 to 0.91)*
Maternal height	
Short (up to 145.0 cm)	2.48 (1.60 to 3.83)***
Average (145.1–155.0 cm)	Ref
Tall (155.1 cm and over)	0.44 (0.32 to 0.57)***
Antenatal care visits	
Fewer than three times	1.65 (0.84 to 3.24)
3–5 times	2.79 (1.35 to 5.30)**
6–10 times	1.41 (0.75 to 2.64)
11 times or more	Ref
Sex of child	
Male	Ref
Female	1.55 (1.24 to 1.95)***
Preceding birth interval	
First birth	Ref
Under 24 months	0.55 (0.32 to 0.92)*
24–47 months	0.46 (0.33 to 0.63)***
48–59 months	0.61 (0.40 to 0.90)*
60 months or more	0.74 (0.55 to 0.98)*
Education level	
No education and primary	Ref
Secondary and passed General Certificate of Education (GCE) O-level	0.59 (0.36 to 0.98)*
Passed GCE A-level	0.38 (0.21 to 0.70)**
Degree and above	0.76 (0.36 to 1.59)
Wealth index quintile	
Lowest	Ref
Second	0.77 (0.54 to 1.08)
Middle	0.81 (0.55 to 1.17)
Fourth	0.63 (0.41 to 0.93)*
Highest	0.43 (0.25 to 0.70)**
Ethnicity	
Sinhala	Ref
Sri Lankan Tamil	0.91 (0.60 to 1.38)
Indian Tamil	2.13 (1.12 to 4.06)*
Muslims	0.71 (0.46 to 1.08)
Burgher and Malay	0.72 (0.08 to 5.90)
Province	
Western	Ref
Central	1.25 (0.81 to 1.91)

Continued

Table 3 Continued

Variable and category	Adjusted OR (95% CI)
Southern	1.02 (0.66 to 1.58)
Northern	0.66 (0.37 to 1.17)
Eastern	1.27 (0.78 to 2.06)
North-Western	1.36 (0.88 to 2.11)
North Central	0.90 (0.53 to 1.52)
Uva	0.96 (0.55 to 1.63)
Sabaragamuwa	1.82 (1.14 to 2.89)*
Mother-level variance (SE)	2.40 (0.324)***
Intracluster correlation coefficient	0.63
Log likelihood	−2,831.64
Akaike information criterion	5735.29
Bayes information criterion	5983.02

***P<0.001; **p<0.01; *p<0.05; Ref: reference category.

hospital settings.[31 32] SLDHS has several limitations. There are no data on genetic factors as well as on nutrition/dietary intake before, during and after pregnancy. However, maternal anthropometric data offer useful proxies to assess the relationship between maternal nutritional status and LBW outcomes. SLDHS has also no data on gestational weight gain and prepregnancy weight: the present study used height and weight data measures at the time of the survey to calculate BMI values. However, maternal weight before and after pregnancy may differ considerably. Therefore, it is recommended that future studies consider both anthropometric measures and pregestational BMI to examine if there is a relationship with birth weight.

CONCLUSION

Our study concludes that lower socioeconomic status mothers, particularly Indian Tamil mothers have higher LBW, and it differs substantially from other groups. Maternal factors such as maternal BMI and height and preceding birth interval along with antenatal care visits have more influence in determining LBW outcome. Socioeconomic and geographic factors such as maternal education, wealth and residential sector are also important determinants of LBW outcomes in Sri Lanka. Public health nutrition policies and programme interventions should address these key factors to reduce the overall burden of LBW, with a focus on the marginalised Indian Tamil mothers and those with lower socioeconomic status.

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Patient consent for publication Not required.

Ethics approval Ethical approval was granted from the Ethics Research and Governance unit of the University of Southampton (reference: 42179).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party but are not publicly available. The data are not publicly available but can be obtained through written request to the Department of Census and Statistics in Sri Lanka.

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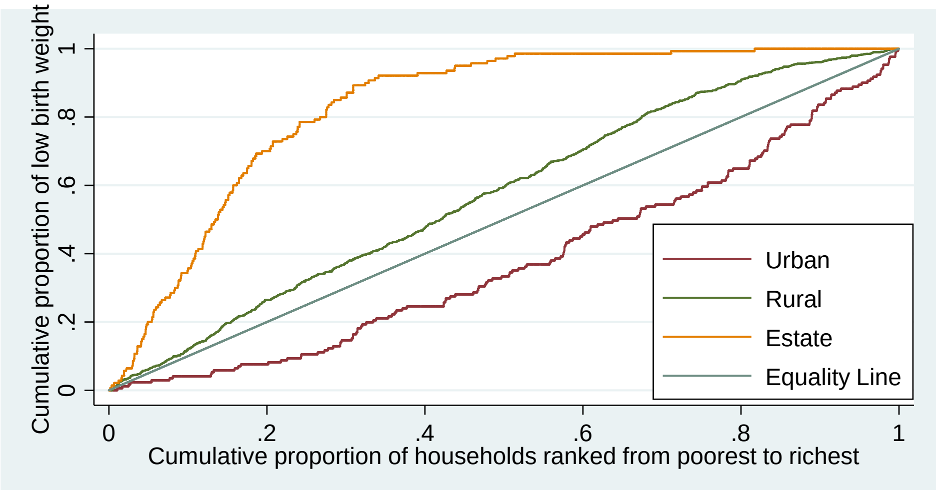
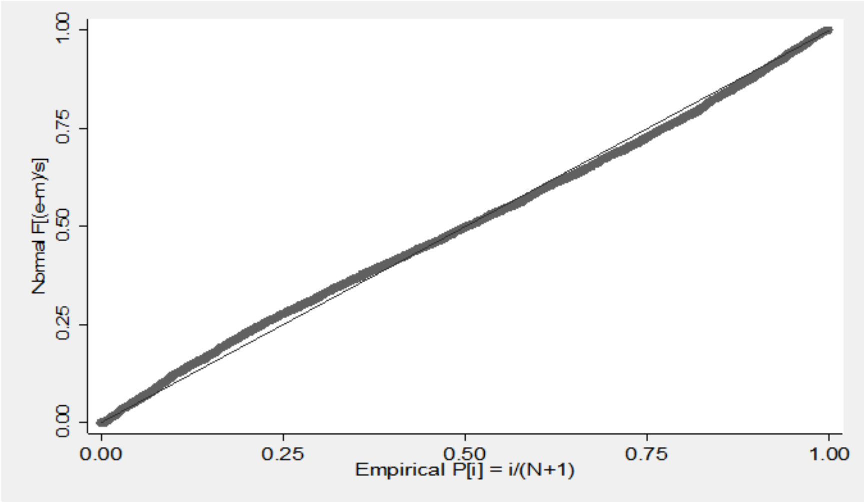
Appendix B Concentration curves for LBW by place of residence



Appendix C Normal probability plot for final model



Appendix D Adjusted final logistic regression model using <2500g low birth weight definition

Variables	AOR (95 per cent CI)
Maternal Body Mass Index	
BMI < 18.5	1.54 (1.29,1.91)***
BMI 18.5-24.9	1.00
BMI 25.0-29.9	0.89 (0.74,1.06)
BMI >= 30.0	0.73 (0.54,0.97)*
Maternal height (cm)	
Short <=145 cm	1.57 (1.22,2.01)***
Average 145.1-155 cm	1.00
Tall 155.1 & over	0.64 (0.54,0.75)***
Number of anc visits	
Below 3 times	1.10 (0.91,1.32)
3-5 times	1.85 (1.49,2.31)***
6-10 times	1.00
11 or more	0.72 (0.46,1.12)
Birth Interval	
First birth	1.00
< 24 months	0.75 (0.51,1.03)
24-47 months	0.59 (0.48,0.73)***
48 months or more	0.71 (0.55,0.92)*
Sex of a child	
Male	1.00
Female	1.45 (1.25,1.67)***
Educational category	
Up to grade 5	1.00
Grade 6 to Ordinary Level	0.91(0.46,1.80)
Advanced Level	0.78 (0.41,1.47)
Degree and above	0.79 (0.38,1.63)
Wealth index	
Lowest	1.00
Second	0.74 (0.59,0.94)*
Middle	0.74 (0.59,0.94)*
Fourth	0.70 (0.54,0.90)**
Highest	0.47 (0.35,0.65)***
Ethnicity	
Sinhala	1.00
Sri Lankan Tamil	0.84 (0.61,1.16)
Indian Tamil	1.62 (0.93,2.81)*
Muslims and others	0.79 (0.58,1.08)
Sector	
Urban	1.00
Rural	0.95 (0.75,1.21)

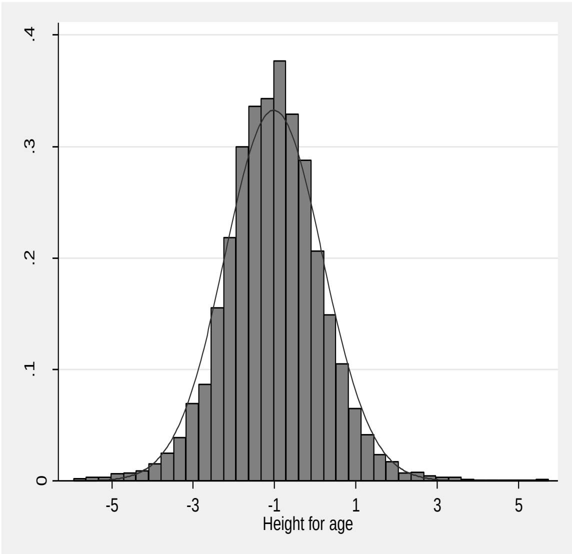
Estate	1.05 (0.66,1.68)
Province	
Western	1.00
Central	0.91 (0.69,1.21)
Southern	0.85 (0.64,1.130
Northern	0.58 (0.37,0.91)
Eastern	0.98 (0.70,1.360
North-Western	0.96 (0.73,1.25)
North-Central	1.00(0.71,1.40)
Uva	0.91 (0.67,1.23)
Sabaragamuwa	1.19 (0.89,1.58)*

Appendix E Wealth status of ethnic groups by sector

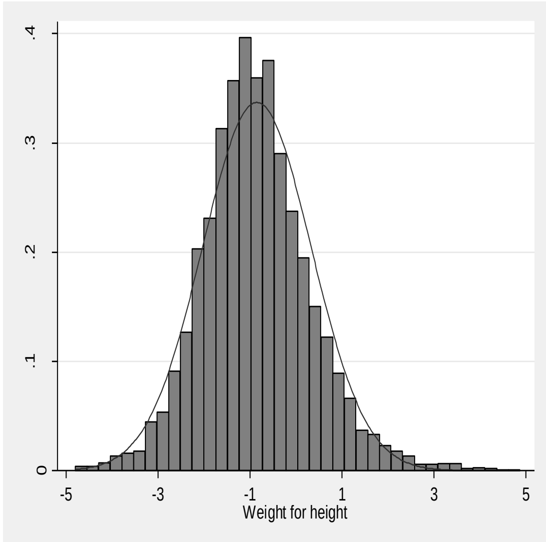
Sector	Wealth Quintiles	Sinhalese	Sri Lankan Tamils	Indian Tamils	Muslims and others	Total
Urban	Lowest	25(4.2)	67 (24.2)	0(0)	14 (4.8)	106(9.3)
	Second	55(9.3)	57 (20.6)	3(33.3)	43 (14.9)	158(13.6)
	Middle	93(15.8)	47 (17.0)	1(11.1)	45 (24.1)	186(16.0)
	Fourth	141 (23.9)	53 (19.2)	4(44.4)	90 (31.2)	288(24.8)
	Highest	274 (46.6)	52(18.8)	1(11.1)	96 (22.7)	423(36.4)
	Total	**588 (100.0)**	**276 (100.0)**	**9 (100.0)**	**288(100.0)**	**1161(100.0)**
Rural	Lowest	622(15.4)	619(60.7)	19(57.5)	123(23.0)	1383(24.6)
	Second	906(22.4)	225(22.0)	5(15.1)	111(20.8)	1247(22.1)
	Middle	930(23.0)	83(8.1)	8(24.2)	111(20.8)	1132(20.1)
	Fourth	927(22.9)	65(6.3)	1(3.0)	113(21.2)	1106(19.6)
	Highest	652(16.1)	27(2.6)	0(0.0)	75(14.0)	754(13.4)
	Total	**4037(100.0)**	**1019(100.0)**	**33(100.0)**	**533(100.0)**	**5622(100.0)**
Estate	Lowest	24(46.1)	160(76.1)	156(77.2)	7(58.3)	347(72.9)
	Second	18(34.6)	36(17.1)	32(15.8)	2(16.6)	88(18.4)
	Middle	6(11.5)	11(5.2)	6(2.9)	3(25.0)	26(5.4)
	Fourth	3(5.7)	2(0.9)	8(3.9)	0(0.0)	13(2.7)
	Highest	1(1.9)	1(0.4)	0(0.0)	0(0.0)	2(0.4)
	Total	**52(100.0)**	**210(100.0)**	**202(100.0)**	**12(100.0)**	**476(100.0)**

Appendix F Histograms for child nutritional outcomes

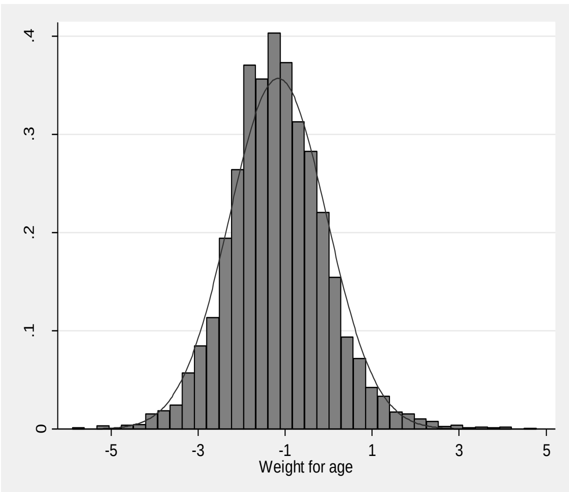
a. Stunting (height-for-age)



b. Wasting (weight-for-height)

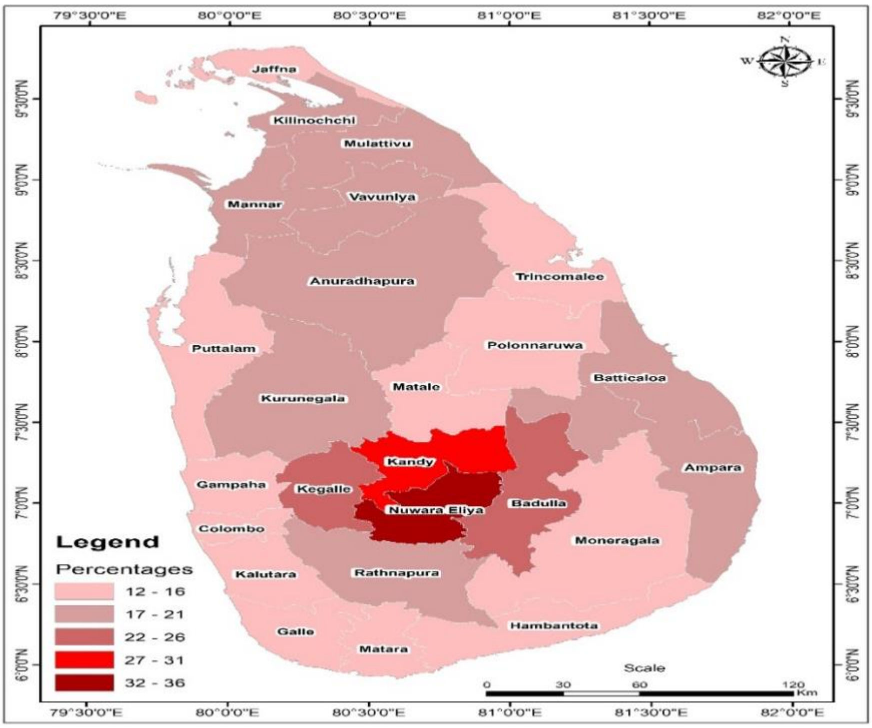


c. Underweight (weight-for-age)

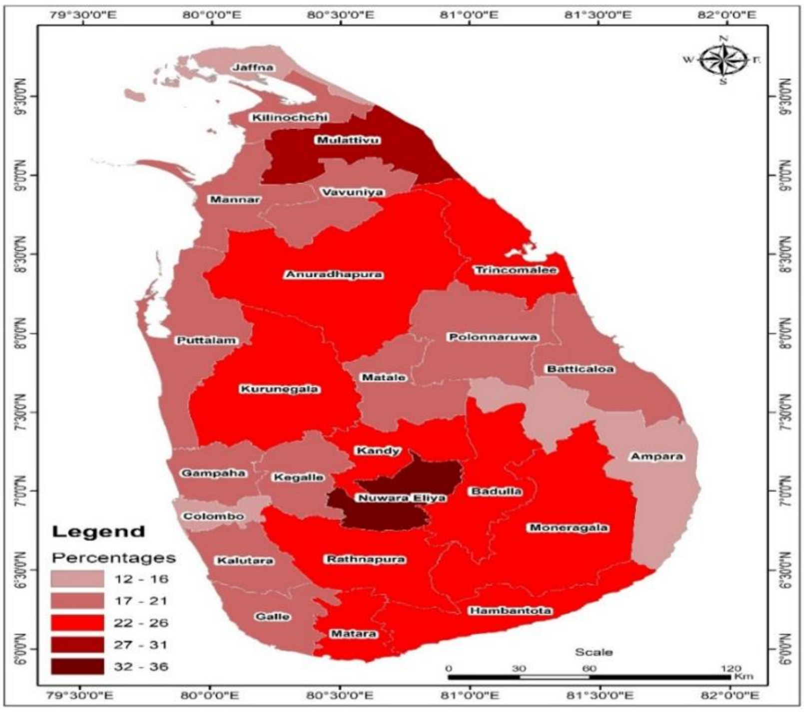


Appendix G Maps for child stunting, wasting and underweight for children aged 6-59 months.

a. Stunting

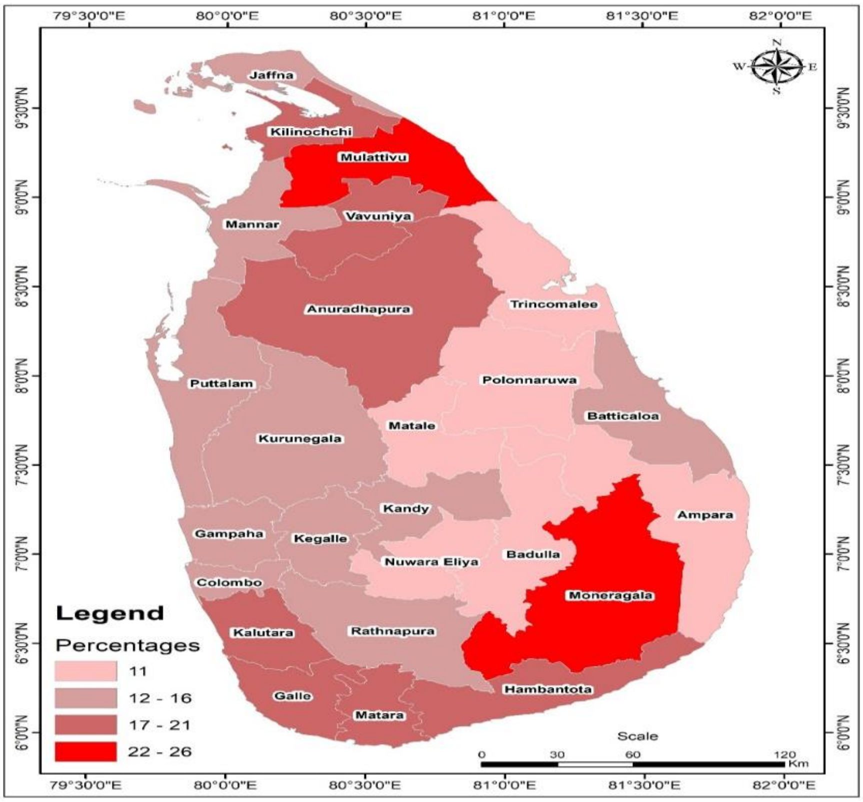


b. Underweight



Appendix G

c. Wasting



Appendix H Models for child stunting and underweight, excluding wealth index

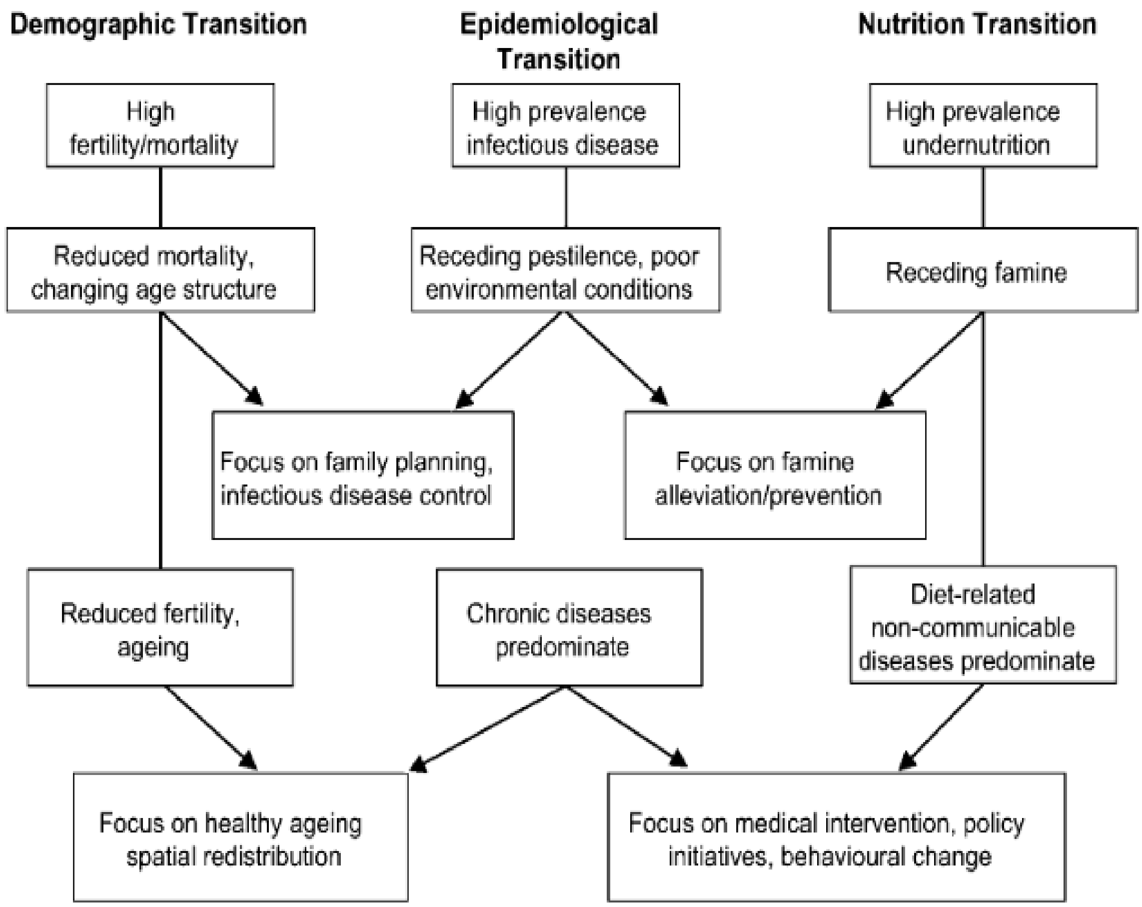
Household variable	**Stunting**	**Underweight**
Source of water		
Improved	1.00	1.00
Not improved	1.28 (1.00,1.63)*	1.20 (0.93,1.54)
Toilet facility		
Improved	1.00	1.00
Not improved	1.24 (0.77,1.99)	1.09 (0.68,1.73)
Available livestock		
Yes	1.00	1.00
No	0.92 (0.74,1.16)	0.79 (0.64,0.98)*
Primary source of cooking		
Modern	1.00	1.00
Traditional	1.11 (0.92,1.33)	1.19 (1.00,1.40)*

Appendix I Results of the multivariate analysis for child underweight for children aged 12-24 months

Characteristics	AOR (95% CI)
Vaccination status	
Partially vaccinated	1.00
Full vaccinated	2.06 (1.31,3.22)**
Age in months	
12,15	1.00
16,20	0.12 (0.02,0.63)*
21,24	0.12 (0.02,0.63)*
Birth Weight	
Normal weight	1.00
Low birth weight(<= 2500 grams)	3.22 (2.26,4.60)***
Birth interval	
First birth	1.00
< 24 months	1.20 (0.61,2.34)
24,47 months	1.32 (0.88,1.99)
48 months or more	0.80 (0.54,1.18)
Sex	
Male	1.00
Female	0.71 (0.51,0.98)
Child feeding and immunisation	
Diarrhoea in last two weeks	
Yes	1.00
No	1.38 (0.57,3.30)
Fever in last two weeks	
Yes	1.00
No	0.73 (0.49,1.09)
Still breastfeeding	
Yes	1.00
No	0.82 (0.45,1.50)
Maternal BMI	
BMI < 18.5	1.07 (0.69,1.64)
BMI 18.5-24.9	1.00
BMI 25.0-29.9	0.53 (0.34,0.82)**
BMI >= 30.0	0.50 (0.28,0.91)*

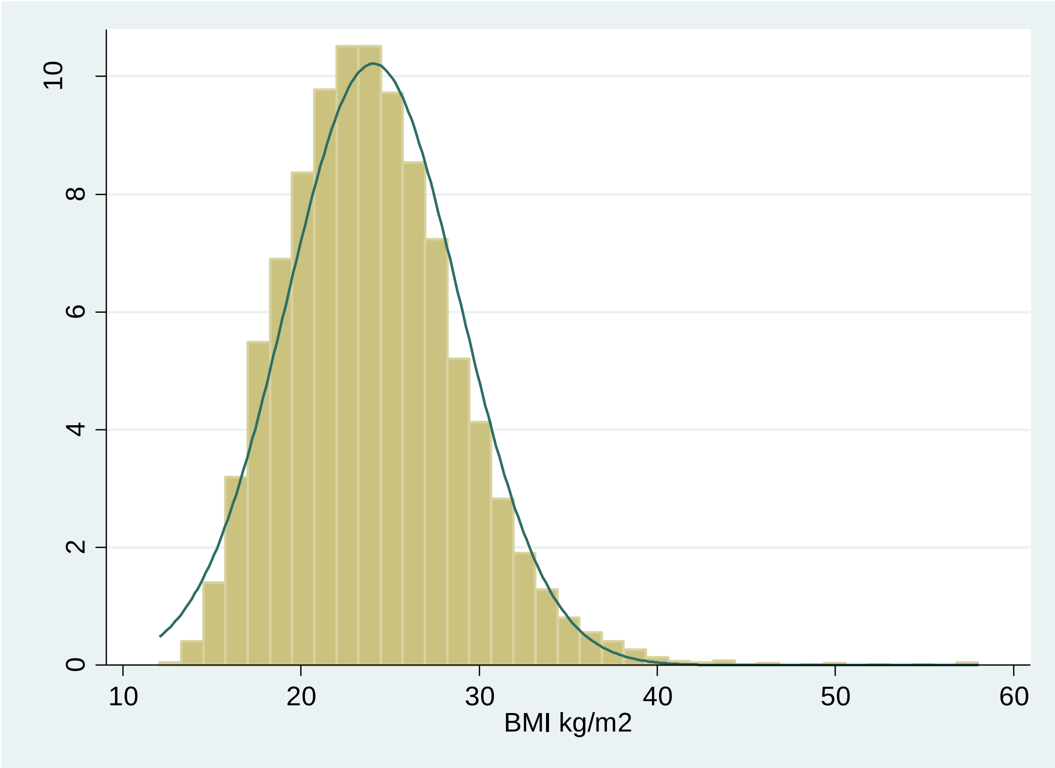
Characteristics	AOR (95% CI)
Maternal height	
Short	1.00
Medium	0.66 (0.36,1.19)
Tall	0.40 (0.21,0.73)**
Maternal education	
Up to grade 5	1.00
Grade 6 to Ordinary Level	0.70 (0.31,1.60)
Advanced Level	0.61 (0.25,1.50)
Degree and above	0.55 (0.18,1.61)
Ethnicity	
Sinhalese	1.00
Sri Lankan Tamil	1.04 (0.56,1.91)
Indian Tamils	0.70 (0.30,1.61)
Muslims and others	1.00 (0.57,1.74)
Wealth index	
Lowest	1.00
Second	0.75 (0.46,1.23)
Middle	0.84 (0.51,1.36)
Fourth	0.53 (0.30,0.91)*
Highest	0.46 (0.24,0.90)*
Province	
Western	1.00
Central	0.92 (0.50,1.66)
Southern	1.13 (0.64,2.00)
Northern	0.46 (0.16,1.27)
Eastern	1.08 (0.57,2.04)
North-Western	1.02 (0.58,1.78)
Nort-,Central	1.02 (0.55,1.90)
Uva	1.04 (0.54,2.01)
Sabaragamuwa	0.65 (0.33,1.28)

Appendix J Stages of nutrition transition

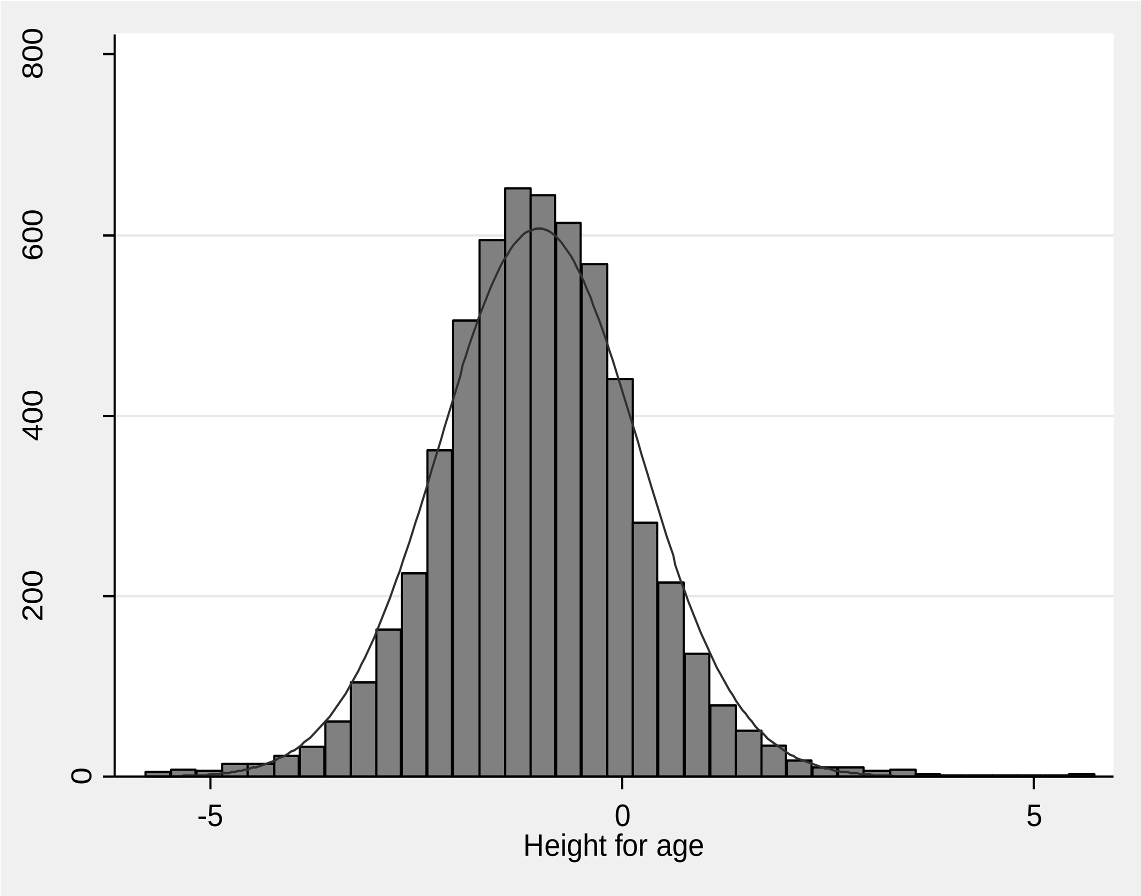


Source: Popkin,2003,p.94

Appendix K Distribution of mothers' body mass index



Appendix L Distribution of height-for-age *z*-scores



Appendix M Distribution of maternal BMI with child stunting status (n=6,929)

	Non stunted		Stunted		Total	
Maternal BMI	N	(%)	N	(%)	N	(%)
BMI <18.5 (thin)	612	76.3	190	23.6	802	100
BMI 18.5- 24.9 (normal)	2733	80.7	650	19.2	3,383	100
BMI 25-29.9 (overweight)	1662	83.8	321	16.1	1,983	100
BMI <30 (obese)	651	85.5	110	14.4	761	100
Total	5,658	81.6	1,271	18.3	6,929	100

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