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Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and health survey 2016

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ABSTRACT

Objective: To investigate social inequalities underlying Low Birth Weight (LBW) outcomes in Sri Lanka.

Design: Cross-sectional study

Setting: This study used the Sri Lanka's Demographic and Health Survey 2016- available since the civil war ended in 2001.

Participants: Birth weight data extracted from the child health development records for 7,964 babies born between January 2011 and the date of interview in 2016.

Outcome measures: The main outcome variable was classified as LBW (=<2500g) and normal.

Methods: We applied random intercept three-level logistic regression to examine the association between LBW and maternal depletion, socioeconomic and geographic variables. Concentration indices were estimated for different population sub-groups.

Results: The population-level prevalence of LBW was 16.9%, significantly higher in the estate sector (28.4%) compared to 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 random intercept models confirmed our hypothesis of significant higher risk of LBW outcomes across poorer households and Indian Tamil communities (AOR:1.70, 95% CI:1.02,2.83, p<0.05). There was substantial unobserved variation in LBW outcomes at the mother level. The effect of maternal depletion 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.

Keywords Low birth weight; social inequalities; maternal depletion

ARTICLE SUMMARY

Strengths and limitations of this study:

- The survey covered the entire island for the first time after the war ended in 2001.
- Birth weight data obtained from child health records and most of the births are institutional deliveries.
- Birth weight data can be biased due to rounding errors or other errors related to weighing instruments.
- Due to data constraints, data on genetic factors and pre-pregnancy weight that could have affected the LBW 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 to other South Asian countries. However, there has been little or no progress in child health indicators in Sri Lanka particularly low birth weight (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 high 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.[4,5-9] 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.[6] 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-and middle-income countries, which account for more than 95% of all LBW babies. South Asia has the largest share of LBW babies (48%),[4,11] with the highest rates recorded in Bangladesh, India and Pakistan.[12] Maternal bio-behavioural risk factors such as age, nutritional status, poor diet during pregnancy, body mass index (BMI), gestational age, inter-pregnancy interval, parity, and lack of antenatal care as well as social, economic and environment factors such as poverty and low socioeconomic status are associated with LBW outcomes.[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] National health programmes promoting universal access to antenatal care, the multi-sectoral food and micronutrient supplementation programme aligned to the National Nutrition Policy (2009 – 2013), and the National Health Policy in 2011 – alongside poverty alleviation programmes were pertinent but contributed little to reducing 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 in richer households in other rural areas, and in towns and cities.

[Figure 1 about here]

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 2001. 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 interviews. SLDHS collected detailed data on birth histories and mothers' reproductive health behaviours, along with socioeconomic and demographic data. Birth weight data were extracted from the child health development records for 8,104 babies born between

January 2011 and the date of interview in 2016. Of these 8,104 babies, birth weight data were available for 7,964 babies.

Outcome variable

We followed the standard definition of LBW (babies weighing less than 2,500 grams) but also considered those with a reported birth weight of exactly 2,500 grams,[22] to allow for potential rounding errors while entering LBW data on child health development records. For 220 cases (2.6% of the total), birth weight was recorded at exactly 2500 grams. We excluded multiple births (1.7%) and extreme cases of birth weights of 6,500 grams or more (0.36%). Our final analysis sample include 7,713 full-term singleton births with a recorded birth weight between January 2011 and November 2016 (survey date).

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 which 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 low birth weight, infant mortality, and reduced fecundity.[23-25] SLDHS has limited variables to measuring maternal depletion: maternal age, maternal BMI and height, preceding birth interval, micronutrient (iron and folic acid tablets) receipt intake and food supplementation (*Thriposha*) received during pregnancy. We also have data on the frequency of antenatal care visits and the sex of the child.

In addition, we considered the following socioeconomic variables: maternal education, a household wealth index as a proxy for measuring socioeconomic status, and ethnicity. Finally, we considered two key geographic variables: residence in the urban, rural or estate sectors, and the province in where the birth took place.

Statistical analysis

We examined the binary association between birth weight and selected characteristics. The outcome variable is coded 0 (reference) for babies with normal weight and 1 for those weighing 2,500 grams 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, and mothers grouped within communities (primary sampling units or clusters), we examine the variation in LBW at three levels: child, mother and community.

Model 1 included maternal depletion variables, Model 2 included material depletion and socioeconomic variables, and Model 3 included maternal depletion, socioeconomic variables and geographical variables. The variance inflation factor was used to check for collinearity and to ensure that the assumptions of multicollinearity were not violated. Due to the hierarchical nature of the data, with some mothers having more than one child, and mothers grouped within communities (primary sampling units or clusters), we examine the variation in LBW at three levels: child, mother and community.

Additionally, we estimated concentration indices to measure the extent of wealth inequalities underlying LBW, which are illustrated graphically using concentration curves.

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 to 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. There was no significant association between LBW and receipt of *Thriposha* during pregnancy. However, LBW was relatively common among mothers who have 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 low birth weight 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 pronounced in northern region.

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)				Number of births
	<=2500	2501-3000	3001-3500	3501-6500	
All	**16.9**	**38.0**	**34.9**	**10.2**	**7,713**
Maternal age (years)					
Under 20	25.6	39.1	31.0	4.0	
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
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
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
Antenatal visits					
Fewer than 3 times	16.9	38.2	35.7	9.0	1378
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
11 or more times	12.3	36.2	38.3	13.0	284
Received *Thriposha*					
Received and consumed	18.5	43.8	30.5	7.3	504
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
Not received and consumed	25.7	36.0	26.6	11.5	1,210
Sex of child					
Male	15.1	37.4	36.3	11.3	4,000
Female	18.7	38.8	33.5	9.0	3,794
Preceding birth interval					
First birth	19.5	40.6	32.0	7.7	3,011
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

Table 1 (contd.)
Percentage distribution of recorded birth weight by maternal depletion, socioeconomic and geographical factors: Sri Lanka, 2016

Variable and category	Birth weight (in grams)				Number of births
	<=2500	2501-3000	3001-3500	3501-6500	
Education level					
No education and primary	27.6	40.2	24.7	7.3	380
Secondary and passed 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					
Poorest	21.4	40.6	29.8	8.0	1,900
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
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
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
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

Source: Sri Lanka Demographic and Health Survey 2016.

The socioeconomic differentials are further illustrated in the concentration curves (Figures 2a and 2b). 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 degree line it shows perfect equality; when it lies below the line, the outcome is more concentrated among the rich sections of the population; if it lies above the 45 degree line, the outcome is more concentrated among the poor individuals in the population.[26]

The results for LBW show a concentration index of -0.13 (95% CI: -0.15, -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 results show that that inequality within each sector is less than inequality overall 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.

[Figures 2a and 2b about here]

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 a low birth weight baby than those with normal BMI levels (adjusted odds ratio AOR: 1.76, 95%CI: 1.41–2.20). 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: 1.02-2.14) and those with a female birth (AOR = 1.39, 95%CI: 1.19-1.63) were more likely to have a LBW baby than those who did not consume iron or folic acid or who has a male baby, respectively. Babies birth 24-47 month after their immediately elder sibling were at lower risk of having LBW than babies born after shorter or longer intervals.

Model 2 added socioeconomic variables. Although the odds ratios for the maternal depletion variables in Models 1 and 2 cannot properly be compared, there was little or no change in the effect of the maternal depletion variables. 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: 0.36–0.69). 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 than Sinhala mothers.

Table 2
Results of the fixed effects multiple logistic regression

Variable and category	Model 1 Adjusted odds ratio (95% CI)	Model 2 Adjusted odds ratio (95% CI)	Model 3 Adjusted odds ratio (95% CI)
Maternal body mass index			
Under 18.5	1.76 (1.41-2.20)***	1.62 (1.29-2.03)***	1.63 (1.31-2.03)***
18.5-24.9	1.00	1.00	1.00
25.0-29.9	0.78 (0.65-0.95)*	0.83 (0.69-1.00)	0.85 (0.71-1.03)
30.0 or more	0.73 (0.55-0.96)*	0.80 (0.60-1.06)	0.74 (0.56-0.98)*
Maternal height			
Short (up to 145.0 cm)	1.91 (1.47-2.74)***	1.76 (1.36-2.29)***	1.74 (1.35-2.24)***
Average (145.1-155.0 cm)	1.00	1.00	1.00
Tall (155.1 cm and over)	0.55 (0.46-0.66)***	0.58 (0.49-0.70)	0.58 (0.49-0.69)***
Antenatal care visits			
Fewer than 3 times	1.30 (0.79-2.15)	1.43 (0.86-2.37)	1.25 (0.81-1.93)
3-5 times	1.73 (1.09-2.73)*	1.78 (1.11-2.85)*	1.75 (1.09-2.81)*
6-10 times	1.13 (0.75-1.70)	1.14 (0.75-1.72)	1.15 (0.76-1.74)
11 or more times	1.00	1.00	1.00
Taken iron and folic acid supplements			
Received and consumed	1.00	1.00	
Not received and consumed	1.48 (1.02-2.14)*	1.43 (0.98-2.08)	
Sex of child			
Male	1.00	1.00	1.00
Female	1.39 (1.19-1.63)***	1.40 (1.20-1.64)***	1.45(0.16-1.67)***
Preceding birth interval			
First birth	1.00	1.00	1.00
Under 24 months	0.68 (0.47-0.98)*	0.67 (0.46-0.96)*	0.73 (0.52-1.04)
24-47 months	0.58 (0.46-0.73)***	0.56 (0.44-0.70)***	0.59 (0.48-0.73)***
48-59 months	0.77 (0.59-1.08)	0.73 (0.56-0.96)*	0.77 (0.59-0.99)*
60 months or more	0.92 (0.76-1.18)	0.85 (0.70-1.04)	0.87 (0.72-1.05)
Education level			
No education and primary		1.00	1.00
Secondary and passed GCE O-level		0.75 (0.55-1.03)	0.80 (0.58-1.10)
Passed GCE A-level		0.58 (0.40-0.84)**	0.63 (0.44-0.90)*
Degree and above		0.90 (0.57-1.44)	0.92 (0.58-1.46)
Wealth index			
Poorest			1.00
Poor		0.82 (0.65-1.04)	0.82 (0.65-1.03)
Middle		0.81 (0.64-1.02)	0.84 (0.66-1.07)
Rich		0.73 (0.56-0.94)*	0.74 (0.58-0.96)*
Richest		0.50 (0.36-0.69)***	0.54 (0.40-0.73)***

Table 2 (contd.)
Results of the fixed effects multiple logistic regression

Variable and category	Model 1	Model 2	Model 3
	Adjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Ethnicity			
Sinhala		1.00	1.00
Sri Lankan Tamil		0.85 (0.68-1.05)	1.03 (0.74-1.43)
Indian Tamil		1.48 (1.03-2.13)*	1.70 (1.02-2.83)*
Muslims		0.82 (0.61-1.11)	0.86 (0.63-1.18)
Burgher and Malay		0.54 (0.16-1.77)	0.43 (0.13-1.45)
Sector			
Urban			1.00
Rural			0.97 (0.77-1.23)
Estate			1.06 (0.66-1.68)
Province			
Western			1.00
Central			0.99 (0.74-1.32)
Southern			1.05 (0.78-1.41)
Northern			0.60 (0.38-0.94)*
Eastern			1.06 (0.76-1.47)
North-Western			1.16 (0.89-1.51)
North Central			0.93 (0.64-1.24)
Uva			0.89 (0.63-1.24)
Sabaragamuwa			1.42 (1.07-1.87)*

****P*<0.001; ***p*<0.01; **p<0.05*

The final model included the geographical variables residential sector and province in addition to maternal and socioeconomic factors. We removed the iron and folic acid variable from the model, as it was no longer significant in Model 2. 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: 1.02–2.83). Similarly, mothers who lived in Sabaragamuwa province had higher odds of LBW than those from the Western province (AOR: 1.42, 95%CI: 1.07–1.87). 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 low birth weight among children born to the same mother, or born within the same community, being correlated. Some of these characteristics can be observed (for example mother's BMI) but others (for example genetic factors) cannot be observed. To assess the magnitude of these correlation effects we estimated a model of low birth weight 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 low birth weight for babies within the same community, but substantial correlation between the risk of low birth weight 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 above 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 (for example maternal height) their impact is amplified.

Table 3
Results of the two-level random intercept logistic regression model

Variable and category	Adjusted odds ratio (95% CI)
Maternal body mass index	
Under 18.5	2.14 (1.48-3.09)***
18.5-24.9	1.00
25.0-29.9	0.71 (0.54-0.94)*
30.0 or more	0.60 (0.39-0.91)*
Maternal height	
Short (up to 145.0 cm)	2.48 (1.60-3.83)***
Average (145.1-155.0 cm)	1.00
Tall (155.1 cm and over)	0.44 (0.32-0.57)***
Number of antenatal care visits	
Fewer than 3 times	1.65 (0.84-3.24)
3-5 times	2.79 (1.35-5.30)**
6-10 times	1.41 (0.75-2.64)
11 times or more	1.00
Sex of child	
Male	1.00
Female	1.55 (1.24-1.95)***
Preceding birth interval	
First birth	1.00
Under 24 months	0.55 (0.32-0.92)*
24-47 months	0.46 (0.33-0.63)***
48-59 months	0.61 (0.40-0.90)*
60 months or more	0.74 (0.55-0.98)*
Educational category	
No education and primary	1.00
Secondary and passed GCE O-level	0.59 (0.36-0.98)*
Passed GCE A-level	0.38 (0.21-0.70)**
Degree and above	0.76 (0.36-1.59)
Wealth index quintile	
Lowest	1.00
Second	0.77 (0.54-1.08)
Middle	0.81 (0.55-1.17)
Fourth	0.63 (0.41-0.93)*
Highest	0.43 (0.25-0.70)**
Ethnicity	
Sinhala	1.00
Sri Lankan Tamil	0.91 (0.60-1.38)
Indian Tamil	2.13 (1.12-4.06)*
Muslims	0.71 (0.46-1.08)
Burgher and Malay	0.72 (0.08-5.90)

Table 3 (contd.)
Results of the two-level random intercept logistic regression model

Variable and category	Adjusted odds ratio (95% CI)
Province	
Western	1.00
Central	1.25 (0.81-1.91)
Southern	1.02 (0.66-1.58)
Northern	0.66 (0.37-1.17)
Eastern	1.27 (0.78-2.06)
North-Western	1.36 (0.88-2.11)
North Central	0.90 (0.53-1.52)
Uva	0.96 (0.55-1.63)
Sabaragamuwa	1.82 (1.14-2.89)*
Mother-level variance (standard error)	2.40 (0.324)***
Intra-cluster correlation coefficient	0.63
Log likelihood	-2,831.6426
Akaike information criterion (AIC)	5,735.285
Bayes information criterion (BIC)	5,983.016

****P*<0.001; ***p*<0.01*; *p<0.05*

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 low birth weight among this group might be attributed to genetic factors deriving from the selected group of poor and destitute Indian Tamils who were originally brought to work in the tea plantations in the nineteenth 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 confirm 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 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 an 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), launched in 1994. This also only provides a modest quantity of monetary support (only 500-1,000 rupees), and does not always target the right beneficiaries.[29-30]

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.

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 hospital settings.[31,32] SLDHS has several limitations. There are no data on genetic factors and gestational age 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 pre-pregnancy weight: the present study used height and weight data measures at the time of the survey to calculate BMI values. On the other hand, maternal weight before and after pregnancy may differ considerably. Therefore, it is recommended that future studies consider both anthropometric measures and pre-gestational BMI to examine if there is a relationship with birth weight.

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Contributorship All authors have substantially contributed to this manuscript.

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Competing Interests None to declare

Ethical Approval Ethical approval was granted from the Ethics Research and Governance unit of the University of Southampton (reference: 42179).

Patient and Public Involvement. This research was done without patient or public involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Data availability. The data are not publicly available but can be obtained through written request to the Department of Census and Statistics in Sri Lanka

Figure legends

Figure 1. Percentage of babies with low birth weight in Sri Lanka: 1990-2017

Figure 2a. Concentration curve showing the cumulative proportion of low birth weight by wealth quintiles

Figure 2b. Concentration curves showing the cumulative proportion of low birth weight by residential sector

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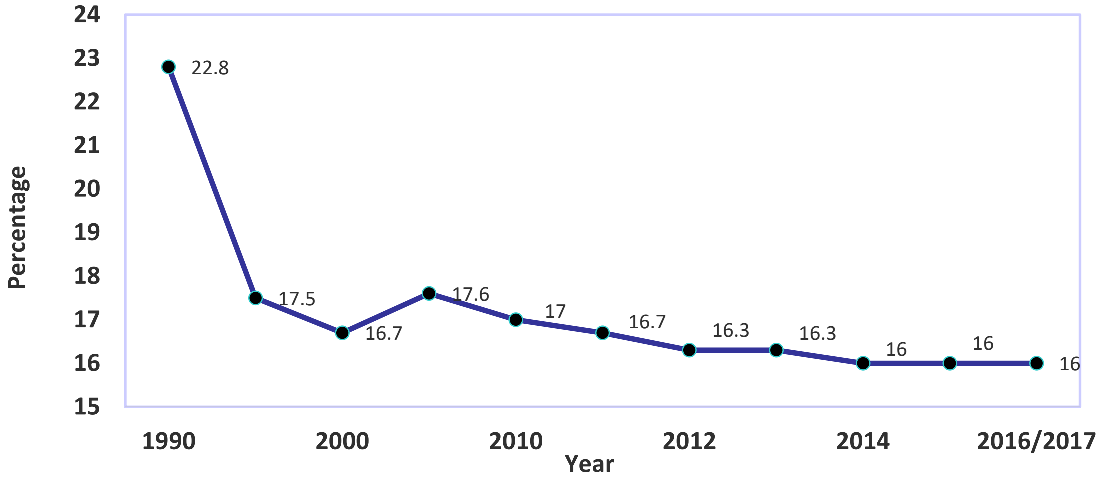
doi: https://doi.org/10.1016/S2214-109X(18)30565-5

Figure 1
Percentage of babies with low birth weight in Sri Lanka: 1990-2017



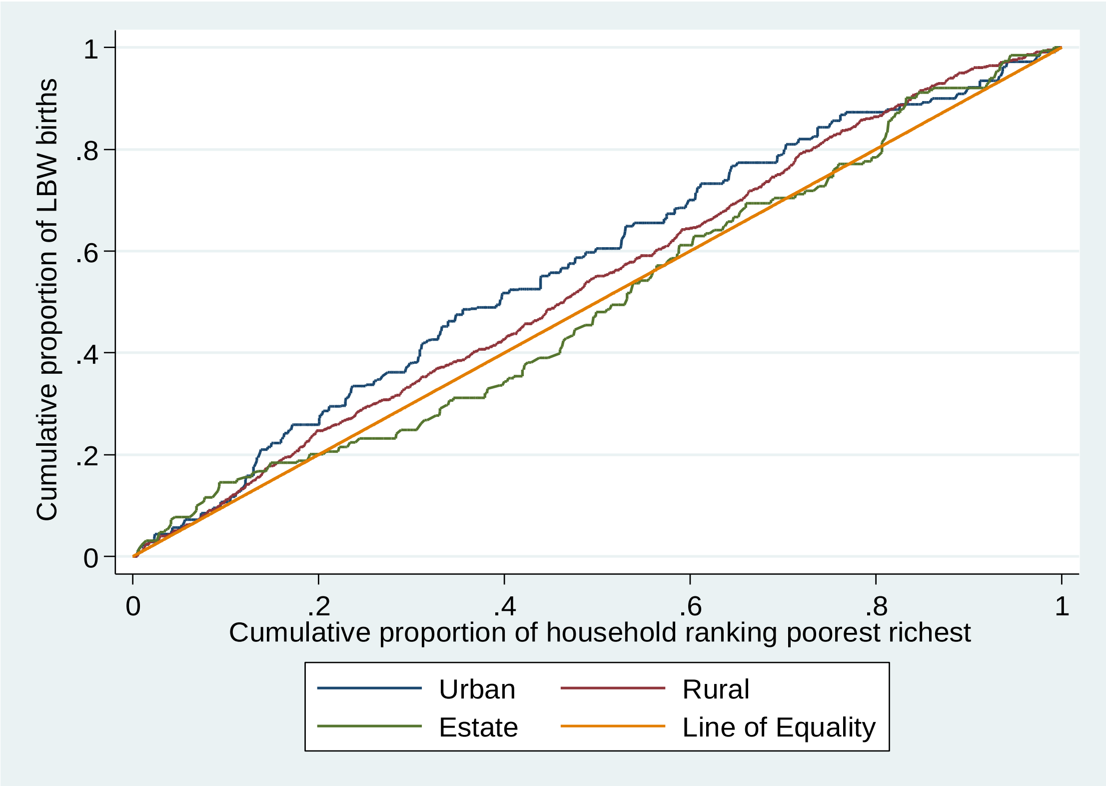
Data source: Department of Census and Statistics[1]

Figure 2a

Concentration curve showing the cumulative proportion of low birth weight by wealth quintiles

Figure 2b

Concentration curves showing the cumulative proportion of low birth weight by residential sector



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Title of the study: **Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and health survey 2016**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2-3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	3-4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	9

		(*c*) Explain how missing data were addressed	Not applicable
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	3
		(*e*) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5-6
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	5-8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-15
		(*b*) Report category boundaries when continuous variables were categorized	9-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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

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

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ABSTRACT

Objective: To investigate social inequalities underlying low birth weight (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 available since the Civil War ended in 2001.

Participants: Birth weight data extracted from the child health development records available for 7,713 babies born between January 2011 and the date of interview in 2016.

Outcome measures: The main outcome variable was birth weight, classified as LBW (=< 2,500g) 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 sub-groups.

Results: The population-level prevalence of LBW was 16.9%, but was significantly higher in the estate sector (28.4%) compared to 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 random intercept models confirmed our hypothesis of significantly higher risk of LBW outcomes across poorer households and Indian Tamil communities (AOR:1.70, 95% CI:[1.02,2.83], $p<0.05$). 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.

Keywords Low birth weight; social inequalities; maternal factors; Demographic and Health Surveys; Sri Lanka

STRENGTHS AND LIMITATIONS OF THIS STUDY

- The survey covered the entire island for the first time after the Civil War ended in 2001.
- Birth weight data were obtained from child health records and most of the births are institutional deliveries.
- Birth weight data can be biased due to rounding errors or other errors related to weighing instruments.
- Due to data constraints, data on genetic factors and pre-pregnancy weight that could have affected the LBW 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 to other South Asian countries. However, there has been little or no progress in child health indicators in Sri Lanka particularly low birth weight (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.[6] 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-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 bio-behavioural risk factors such as age, nutritional status, poor diet during pregnancy, body mass index (BMI), gestational age, inter-pregnancy 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.[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] National health programmes promoting universal access to antenatal care, the multi-sectoral food and micronutrient supplementation programme aligned to the National Nutrition Policy (2009–2013), and the National Health Policy in 2011 – alongside poverty alleviation programmes were pertinent but contributed little to reducing 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 in richer households in other rural areas, and in towns and cities.

[Figure 1 about here]

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 2001. 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 7,072 mothers of reproductive age (15-49 years) who had at least one birth in the five years preceding the survey: 6,069 had one birth, and 1,003 had two or more births, of whom 27 had three and 1 had four children. The total number of births to the 7,072 mothers was 8,104. Of these, 7,964 were singleton (98.3%) and 140 (1.7%) were multiple births. For 251 singleton births, either the birth weight data were missing or the reported birth weight was extreme (over 6,500 grams (0.36% of births)).

For the remaining 7,713 births, the mean birth weight was 2,917 grams (95% CI: [2,906, 2,927]) and the median was 2,920 grams. For 140 multiple births, the mean birth weight was 2,135 grams (95% CI: [2,050, 2,214]) and the median was 2,175 grams. We excluded multiple births in the further analysis, since 81% of the multiple births had low birth weight. 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 2,500 grams. Our final analysis sample includes 7,713 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 2,500 grams) but also considered those with a reported birth weight of exactly 2,500 grams,[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 which 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 low birth weight, 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 comprised 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 2,500 grams 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 to 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 low birth weight 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).

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)				Number of births	P-value
	<=2500	2501-3000	3001-3500	3501-6500		
All data	**16.9**	**38**	**34.9**	**10.2**	**7,713**	
Maternal age (years)						
Under 20	25.6	39.1	31	4	74	0.001
20-24	19.7	41.9	31.2	7.1	1,012	
25-34	16.1	37.8	35.9	10	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	34.8	39.5	13.5	2,821	
Preceding birth interval						
First birth	19.5	40.6	32	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	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	10.3	6,503	0.000
Not received and consumed	25.7	36	26.6	11.5	1,210	
Antenatal visits						
Fewer than 3 times	16.9	38.2	35.7	9	1378	0.041
3-5 times	24	37.1	30.6	8.1	737	
6-10 times	16.1	38.1	35	10.6	5,314	
11 or more times	12.3	36.2	38.3	13	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	3,794	

Table 1 (contd.)
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
Education level						
No education and primary	27.6	40.2	24.7	7.3	380	0.000
Secondary and passed 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						
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	

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

Data source: Sri Lanka Demographic and Health Survey 2016.

The socioeconomic differentials are further illustrated in the concentration curves (Figures 2a and 2b). 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 45^0 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 degree 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, -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.

[Figures 2a and 2b about here]

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 a low birth weight baby than those with normal BMI levels (adjusted odds ratio AOR: 1.76, 95%CI:[1.41–2.20]). 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:[1.02-2.14]) and those with a female birth (AOR = 1.39, 95%CI: [1.19-1.63]) were more likely to have a LBW baby than those who did not consume iron or folic 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:[0.46-0.73])

Model 2 added socioeconomic variables. Although the odds ratios for the maternal depletion variables in Models 1 and 2 cannot properly be compared because 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, 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:[0.36–0.69]). 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 to Sinhala mothers (AOR=1.48, 95%CI:[1.03-2.13]).

(Table 2 about here)

Table 2
Results of the fixed effects multiple logistic regression

Variable and category	Model 1 Adjusted odds ratio (95% CI)	Model 2 Adjusted odds ratio (95% CI)	Model 3 Adjusted odds ratio (95% CI)
Maternal body mass index			
Under 18.5	1.76 (1.41-2.20)***	1.62 (1.29-2.03)***	1.63 (1.31-2.03)***
18.5-24.9	Ref	Ref	Ref
25.0-29.9	0.78 (0.65-0.95)*	0.83 (0.69-1.00)	0.85 (0.71-1.03)
30.0 or more	0.73 (0.55-0.96)*	0.80 (0.60-1.06)	0.74 (0.56-0.98)*
Maternal height			
Short (up to 145.0 cm)	1.91 (1.47-2.74)***	1.76 (1.36-2.29)***	1.74 (1.35-2.24)***
Average (145.1-155.0 cm)	Ref	Ref	Ref
Tall (155.1 cm and over)	0.55 (0.46-0.66)***	0.58 (0.49-0.70)	0.58 (0.49-0.69)***
Preceding birth interval			
First birth	Ref	Ref	Ref
Under 24 months	0.68 (0.47-0.98)*	0.67 (0.46-0.96)*	0.73 (0.52-1.04)
24-47 months	0.58 (0.46-0.73)***	0.56 (0.44-0.70)***	0.59 (0.48-0.73)***
48-59 months	0.77 (0.59-1.08)	0.73 (0.56-0.96)*	0.77 (0.59-0.99)*
60 months or more	0.92 (0.76-1.18)	0.85 (0.70-1.04)	0.87 (0.72-1.05)
Antenatal care visits			
Fewer than 3 times	1.30 (0.79-2.15)	1.43 (0.86-2.37)	1.25 (0.81-1.93)
3-5 times	1.73 (1.09-2.73)*	1.78 (1.11-2.85)*	1.75 (1.09-2.81)*
6-10 times	1.13 (0.75-1.70)	1.14 (0.75-1.72)	1.15 (0.76-1.74)
11 or more times	1.00	1.00	1.00
Taken iron and folic acid supplements			
Received and consumed	Ref	Ref	
Not received and consumed	1.48 (1.02-2.14)*	1.43 (0.98-2.08)	
Antenatal care visits			
Fewer than 3 times	1.30 (0.79-2.15)	1.43 (0.86-2.37)	1.25 (0.81-1.93)
3-5 times	1.73 (1.09-2.73)*	1.78 (1.11-2.85)*	1.75 (1.09-2.81)*
6-10 times	1.13 (0.75-1.70)	1.14 (0.75-1.72)	1.15 (0.76-1.74)
11 or more times	1.00	1.00	1.00
Sex of child			
Male	Ref	Ref	Ref
Female	1.39 (1.19-1.63)***	1.40 (1.20-1.64)***	1.45(0.16-1.67)***
Education level			
No education and primary		Ref	Ref
Secondary and passed GCE O-level		0.75 (0.55-1.03)	0.80 (0.58-1.10)
Passed GCE A-level		0.58 (0.40-0.84)**	0.63 (0.44-0.90)*
Degree and above		0.90 (0.57-1.44)	0.92 (0.58-1.46)

Table 2 (contd.)

Results of the fixed effects multiple logistic regression

Variable and category	Model 1 Adjusted odds ratio (95% CI)	Model 2 Adjusted odds ratio (95% CI)	Model 3 Adjusted odds ratio (95% CI)
Wealth index			
Poorest		Ref	Ref
Poor		0.82 (0.65-1.04)	0.82 (0.65-1.03)
Middle		0.81 (0.64-1.02)	0.84 (0.66-1.07)
Rich		0.73 (0.56-0.94)*	0.74 (0.58-0.96)*
Richest		0.50 (0.36-0.69)***	0.54 (0.40-0.73)***
Ethnicity			
Sinhala		Ref	Ref
Sri Lankan Tamil		0.85 (0.68-1.05)	1.03 (0.74-1.43)
Indian Tamil		1.48 (1.03-2.13)*	1.70 (1.02-2.83)*
Muslims		0.82 (0.61-1.11)	0.86 (0.63-1.18)
Burgher and Malay		0.54 (0.16-1.77)	0.43 (0.13-1.45)
Sector			
Urban			Ref
Rural			0.97 (0.77-1.23)
Estate			1.06 (0.66-1.68)
Province			
Western			Ref
Central			0.99 (0.74-1.32)
Southern			1.05 (0.78-1.41)
Northern			0.60 (0.38-0.94)*
Eastern			1.06 (0.76-1.47)
North-Western			1.16 (0.89-1.51)
North Central			0.93 (0.64-1.24)
Uva			0.89 (0.63-1.24)
Sabaragamuwa			1.42 (1.07-1.87)*

****P*<0.001; ***p*<0.01; **p<0.05; Ref: reference category*

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:[1.02–2.83]). Similarly, mothers who lived in Sabaragamuwa province had higher odds of LBW than those from the Western province (AOR: 1.42, 95%CI:[1.07–1.87]). 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 low birth weight among children born to the same mother, or born within the same community, being correlated. Some of these characteristics can be observed (for example mother's BMI) but others (for example genetic factors) cannot be observed. To assess the magnitude of these correlation effects we estimated a model of low birth weight 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 low birth weight for babies within the same community, but substantial correlation between the risk of low birth weight 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 above 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 (for example maternal height) their impact is amplified

(Table 3 about here)

Table 3
Results of the two-level random intercept logistic regression model

Variable and category	Adjusted odds ratio (95% CI)
Maternal body mass index	
Under 18.5	2.14 (1.48-3.09)***
18.5-24.9	Ref
25.0-29.9	0.71 (0.54-0.94)*
30.0 or more	0.60 (0.39-0.91)*
Maternal height	
Short (up to 145.0 cm)	2.48 (1.60-3.83)***
Average (145.1-155.0 cm)	Ref
Tall (155.1 cm and over)	0.44 (0.32-0.57)***
Number of antenatal care visits	
Fewer than 3 times	1.65 (0.84-3.24)
3-5 times	2.79 (1.35-5.30)**
6-10 times	1.41 (0.75-2.64)
11 times or more	Ref
Sex of child	
Male	Ref
Female	1.55 (1.24-1.95)***
Preceding birth interval	
First birth	Ref
Under 24 months	0.55 (0.32-0.92)*
24-47 months	0.46 (0.33-0.63)***
48-59 months	0.61 (0.40-0.90)*
60 months or more	0.74 (0.55-0.98)*
Educational category	
No education and primary	Ref
Secondary and passed GCE O-level	0.59 (0.36-0.98)*
Passed GCE A-level	0.38 (0.21-0.70)**
Degree and above	0.76 (0.36-1.59)
Wealth index quintile	
Lowest	Ref
Second	0.77 (0.54-1.08)
Middle	0.81 (0.55-1.17)
Fourth	0.63 (0.41-0.93)*
Highest	0.43 (0.25-0.70)**
Ethnicity	
Sinhala	Ref
Sri Lankan Tamil	0.91 (0.60-1.38)
Indian Tamil	2.13 (1.12-4.06)*
Muslims	0.71 (0.46-1.08)
Burgher and Malay	0.72 (0.08-5.90)

Table 3 (contd.)
Results of the two-level random intercept logistic regression model

Variable and category	Adjusted odds ratio (95% CI)
Province	
Western	Ref
Central	1.25 (0.81-1.91)
Southern	1.02 (0.66-1.58)
Northern	0.66 (0.37-1.17)
Eastern	1.27 (0.78-2.06)
North-Western	1.36 (0.88-2.11)
North Central	0.90 (0.53-1.52)
Uva	0.96 (0.55-1.63)
Sabaragamuwa	1.82 (1.14-2.89)*
Mother-level variance (standard error)	2.40 (0.324)***
Intra-cluster correlation coefficient	0.63
Log likelihood	-2,831.6426
Akaike information criterion (AIC)	5,735.285
Bayes information criterion (BIC)	5,983.016

****P*<0.001; ***p*<0.01; **p<0.05; Ref: reference category*

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 low birth weight among this group might be attributed to genetic factors 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 nineteenth 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), launched in 1994. This also only provides a modest quantity of monetary support (only 500-1,000 rupees)(around 2.75-5.5 US$), 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 foetus, 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 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 pre-pregnancy weight: the present study used height and weight data measures at the time of the survey to calculate BMI values. On the other hand, maternal weight before and after pregnancy may differ considerably. Therefore, it is recommended that future studies consider both anthropometric measures and pre-gestational 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 and Public Involvement. This research was done without patient or public involvement. Patients were not invited to comment on the study design and were not consulted to develop patient relevant outcomes or interpret the results. Patients were not invited to contribute to the writing or editing of this document for readability or accuracy.

Data availability. The data are not publicly available but can be obtained through written request to the Department of Census and Statistics in Sri Lanka

Figure legends

Figure 1. Percentage of babies with low birth weight in Sri Lanka: 1990-2017

Figure 2a. Concentration curve showing the cumulative proportion of low birth weight by wealth quintiles

Figure 2b. Concentration curves showing the cumulative proportion of low birth weight by residential sector

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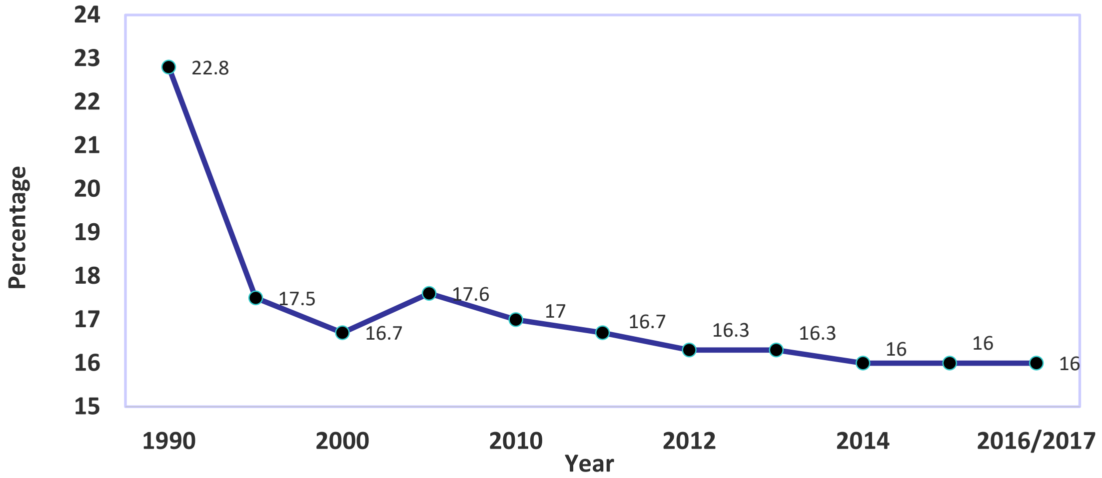
32 Blencowe H, Krasevec J, de Onis M, Black RE, An X, Stevens GA, et al. National, regional, and worldwide estimates of low birthweight in 2015, with trends from 2000: a systematic analysis. *The Lancet Global Health* 2019, 7: e849-e860. doi: https://doi.org/10.1016/S2214-109X(18)30565-5

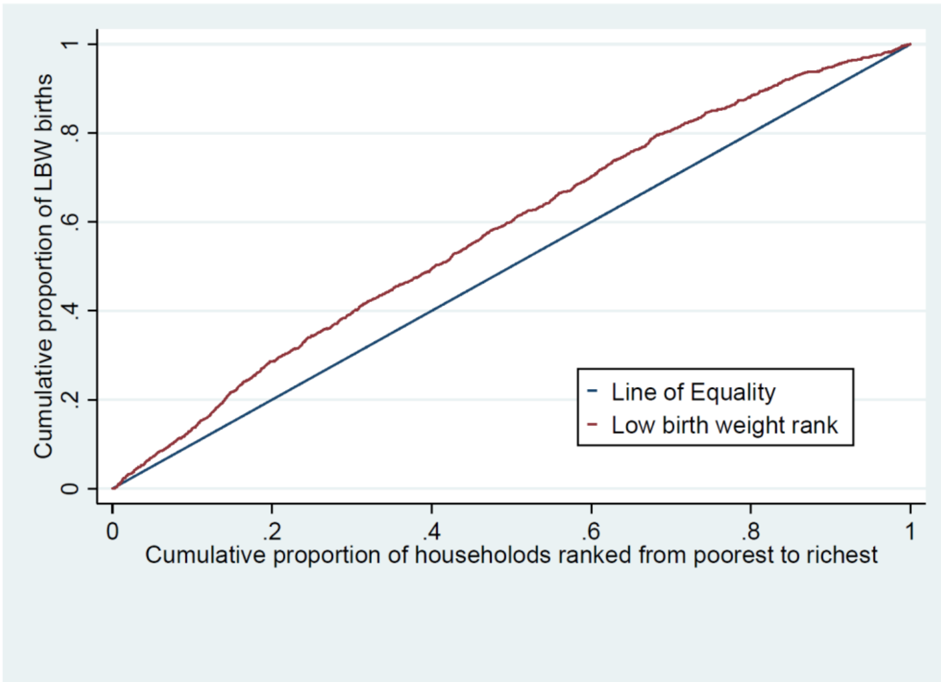
Figure 1
Percentage of babies with low birth weight in Sri Lanka: 1990-2017



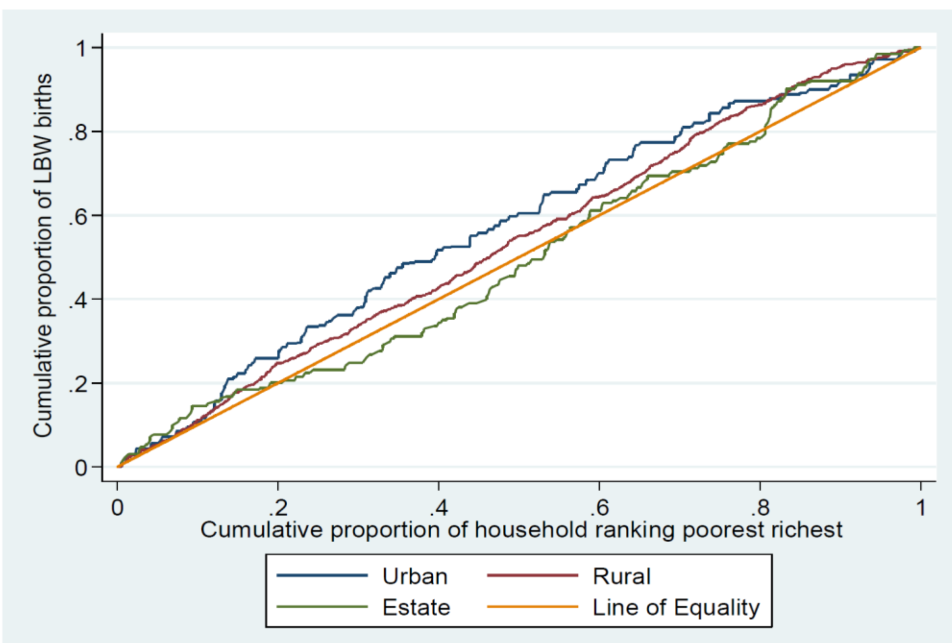
Data source: Department of Census and Statistics[1]

Figure 2
Concentration curves showing the cumulative proportion of low birth weight

(a) By wealth quintile



(b) By residential sector



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of cross-sectional studies

Title of the study: **Social inequalities in low birth weight outcomes in Sri Lanka: evidence from the Demographic and Health Survey 2016**

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	5-6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	5-6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-8
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7-8
		(b) Describe any methods used to examine subgroups and interactions	8-11

		(c) Explain how missing data were addressed	Not applicable
		(d) If applicable, describe analytical methods taking account of sampling strategy	5
		(e) Describe any sensitivity analyses	Not applicable
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-11
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	8-11
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-17
		(b) Report category boundaries when continuous variables were categorized	9-10
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Not applicable
Discussion			
Key results	18	Summarise key results with reference to study objectives	17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	19
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17-19
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-20
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	20

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.