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Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS)

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Abstract

Background: Under-nutrition contributes to childhood morbidity and mortality, particularly in low-income countries. While Rwanda is one of few countries on track to reduce the prevalence of underweight children under five years old by 50 % from 1990 to 2015 (a target of Millennium Development Goal1), underweight children remain a large public health problem with one out of ten children having low weight-for-age.

Methods: We performed a cross-sectional study using 2010 RDHS data on 4177 children under five years of age with weight and height measurements. Children were classified as underweight if their weight-for-age Z scores (WAZs) were <2 standard deviations (SD) and severely underweight if WAZs were <3 SD from the mean of the reference population. We used multivariable logistic regression model to identify child, maternal, and household characteristics associated with being underweight.

Results: Eleven percent (469) of the 4177 children sampled were underweight and 2.2 % (90) were severely underweight. After adjusting for possible confounders, we found that children were more likely to be underweight if they were male (OR = 1.42, 95 % confidence interval (CI):1.12, 1.79); had fever in the two weeks prior to survey administration (OR = 1.45, 95 % CI:1.07, 1.97) or were non-singletons compared to first-born singletons (OR = 4.04, 95 % CI:2.12, 7.71). Mothers were more likely to have underweight children if they were over 35 years of age compared to those age 17–24 years (OR = 1.67, 95 % CI:1.04, 2.70); with BMI <18.5 compared to BMI between 18.5 to 24.9 (OR = 2.62, 95 % CI:1.70, 4.04), who had no education or primary education only (OR = 3.56, 95 % CI:1.83, 6.95; OR = 3.49, 95 % CI:1.87, 6.51, respectively) compared to secondary education or higher, and those who did not have delivery assisted by a skilled provider (OR = 1.33, 95 % CI:1.04, 1.72). Household characteristics associated with underweight children included status in the bottom two wealth quintiles compared to the highest (OR = 1.71, 95 % CI:1.27, 2.30).

Conclusion: Rwanda was one of the first countries to achieve Millennium Development Goal1. However, even in light of this success, the prevalence of underweight children remains high. Our analysis of specific child, maternal and household risk factors for under-nutrition may help identify potential interventions to address this remaining burden.

Keywords: Africa, Under-nutrition, DHS, Underweight

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Background

Under-nutrition remains one of the most common causes of morbidity and mortality among children under five years of age in developing countries [1]. In 2011, 16 % of children under five were underweight (low weight-for-age) in developing countries and 45 % of under-five deaths were directly or indirectly linked to under-nutrition [2]. Despite global improvements, the prevalence of underweight children under five is still a major public health problem in sub-Saharan Africa [2] and many countries have failed to achieve the first Millennium Development Goal (MDG 1) that called for the eradication of extreme hunger and the reduction of the prevalence of underweight children by 50 % from 1990 to 2015 [3, 4].

Anthropometric indicators such as weight-for-height (wasting), height-for-age (stunting) and weight-for-age (underweight) are used to evaluate the nutrition status of children. Stunting results from chronic under-nutrition, which retards linear growth, while inadequate nutrition over a shorter period results in wasting [5]. Underweight is thought to encompass both stunting and wasting although some surveys find that a small percentage of children are underweight but do not meet the definition of either stunting or wasting. We chose to study risk factors for the primary MDG1 measurement indicator, being underweight. Although the choice of indicator for MDG 1 was controversial, a comparison of the three indicators using DHS data from Kenya suggests that underweight is reliable indicator of overall child growth [6]. Poverty is chief among the determinants of low weight-for-age, which also include household food insecurity and inadequate intake of nutrients [7], poor childcare practices, unhealthy living environments that contribute to frequent infection [8, 9], poor health care and maternal under-nutrition leading to low birth-weight [1, 4, 8].

Rwanda achieved MDG1 in 2010 [3], with the prevalence of under nutrition falling by 62 % from 29 % in 1992 [9] to 11 % in 2010 [10]. Further, stunting decreased from 48 % to 44 % and wasting from 3.8 % to 2.8 % in this same time period [10]. Although results of the 2015 DHS are not yet available, further declines in undernutrition are expected to have occurred in the past five years. Despite having a low prevalence of underweight children compared to its neighboring countries, (29 % in Burundi, 24 % in Democratic Republic of Congo and 16 % in Tanzania) [3] and despite significant recent improvements, one in ten children in Rwanda was still underweight in 2010 [10]. This rate is high in comparison with developed economies, where the prevalence of underweight children is less 2.5 % [11]. The DHS report provided descriptive information on the proportion of the population that was underweight but did not analyze risk factors for being underweight. We conducted this analysis to help identify potential interventions to address the problem. In this paper, we aim to identify risk factors for being underweight in the context of intensive nutrition interventions, that may be useful for informing policy and indicator-specific programming to resolve the underweight problem in order to close this gap and further reduce the prevalence of underweight children in Rwanda.

Methods

Data sources

This analysis of the 2010 Rwanda Demographic and Health Survey (RDHS) includes data on children under five years of age, their mothers and households [10]. The 2010 RDHS was a nationally representative sample of 13,671 women age 15 to 49 years from 12,540 households. The study used a two-stage cluster design, stratified by Rwanda's 30 districts. In the first stage, 492 villages were selected from a national listing of all villages with probability proportionate to the number of households in each village. In the second stage, surveyors mapped and systematically sampled every tenth household within a sampled village until the 12,540 household sample was reached. All women age 15 to 49 in selected households were invited to participate. The questionnaires were administered orally in Kinyarwanda.

In half of all households, anthropometric measurements were taken for all children under five years of age. To be eligible, children must have spent the night before the survey in the household. Child weight was measured with a lightweight electronic scale [10]. Very young children were weighed with the respondent standing on the scale and the child's weight estimated by subtracting the respondent's weight [10]. Children's ages were ascertained from mothers who supplied the date of birth. Socio-economic status was provided by DHS based on a principal components analysis of survey responses ownership of specified durable goods (television, radio, car, mobile telephone, etc.) and housing characteristics (access to electricity, source of drinking water, type of toilet facilities, type of flooring material, number of rooms used for sleeping, and type of cooking fuel).

Data analysis

We used the recorded weight and age of each child to create an underweight variable; we classified children as underweight if their weight-for-age was less than two standard deviations from the reference population and severely underweight if WAZ was less than three standard deviations, as wasted if weight-for-height was less than two standard deviations and as stunted if height-for-age was less than two standard deviations [10]. We considered the following child, maternal and household variables as potential predictors of being underweight: a) child's gender, age in months, size at birth, birth interval

Table 1 Socio-demographic characteristics of mothers and children under 5 years old in Rwanda DHS 2010

Characteristic	N (weighted)	%
Underweight (weight-for-age < -2sd) (N = 4,117)		
No	3708	88.6
Yes	469	11.4
Severe underweight (weight-for-age < -3sd) (N = 4,117)		
No	4027	97.8
Yes	90	2.2
Child age (N = 4,177)		
< 12 months	793	19.0
12–23 months	800	19.1
24–35 months	900	21.5
36–47 months	845	20.2
48–59 months	839	20.1
Child sex (N = 4,176)		
Boys	2101	50.3
Girls	2075	49.7
Child size at birth (N = 4,159)		
Not small at birth	3521	84.7
Small at birth	638	15.3
Birth interval (from previous birth) (N = 4,176)		
Singleton first-born	1014	24.3
Singleton birth <2 years	624	14.9
Singleton birth > =2 years	2437	58.4
Multiple births	101	2.4
Mother age in year (N = 4,176)		
15–24	755	18.1
25–34	2255	54.0
35–49	1166	27.9
Mother's highest level of educational (N = 4,176)		
No education	803	19.2
Primary	3016	72.2
Secondary or higher	357	8.6
Mother occupation (N = 4,174)		
Not working	415	9.9
Skilled worker	374	9.0
Unskilled worker	3385	81.1
Marital status (N = 4,174)		
Single	255	6.1
Married/partnered	3573	85.6
Separated/divorced	348	8.3
Delivery assisted by health professional (N = 4,176)		
Yes	2919	69.9
No	1257	30.1

Table 1 Socio-demographic characteristics of mothers and children under 5 years old in Rwanda DHS 2010 *(Continued)*

	N (weighted)	%
Sex of the household head (N = 4,176)		
Female	877	21.0
Male	3299	79.0
Residence (N = 4,176)		
Urban	484	11.6
Rural	3692	88.4
Wealth quintile (N = 4,176)		
Top 2	1480	35.4
Middle	848	20.3
Bottom 2	1848	44.2
Toilet cleanness upon inspection (N = 4,159)		
Not cleaned	2717	65.3
Yes cleaned	1442	34.7
Quality of toilet (N = 4,075)		
Unimproved shared	203	5.0
Improved shared	575	14.1
Improved not shared	2431	59.7
Unimproved not shared	866	21.2
Proximity to improved water source (N = 4,155)		
Water on premise	167	4.0
< 30 minutes	1787	43.2
> =30 minutes	2181	52.7
Missing	42	
Water treatment (N = 4,177)		
No	2118	50.7
Yes	2058	49.3
Missing	1	
Total	4177	100

and whether the child was a singleton, breastfeeding practice, recent deworming, diarrhea in the last two weeks and fever in the last two weeks; b) mother's age, body mass index (BMI), education, occupation, antenatal care visits during the last pregnancy, delivery assistance for the last pregnancy and smoking behavior; and c) household's urban/rural residence, number of household members, sex of the head of household, wealth quintile and sanitation characteristics including access to improved drinking water source, water treatment measures, proximity to improved water source, having an improved toilet, toilet sharing and child stool disposal. We defined improved drinking water source as water coming from a protected spring or a public tap or standpipe. We considered drinking water to have been treated if it was boiled, treated with chlorine, sand, filter or solar disinfection. We defined proximity to improved water source as having water on the premises or obtainable within a 30 min walk.

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We considered toilet facilities to be improved if they consisted of a pit latrine with a slab or a flush toilet to a piped sewer system or septic tank. We considered a shared toilet to be one that is routinely used by people other than members of the household. We considered children's stools to have been safely disposed of if the child used a toilet or latrine, if the fecal matter was put/rinsed into a toilet or latrine or if it was put into a piped sewer system/ septic tank/pit latrine or a ventilated pit latrine.

We presented the estimated relative frequencies of seven anthropometric categories by pie chart. We assessed risk factors for being underweight using univariable and multivariable logistic regression. All variables associated with being underweight in the univariable analysis at the α = 0.10 significance level were considered in the multivariable model. We also assessed whether there was an interaction between the effect of child's birth size and current age on being underweight. We developed the final multivariable model through backwards-stepwise regression. Variables were ordered by level of impact on underweight status based on previous literature and the UNICEF nutrition framework [3], and we removed variables one at a time if $p > 0.05$, stopping when all remaining variables were statistically significant. We report odds ratios and corresponding 95 % confidence intervals. Sampling weights were applied to all observations to compensate for over-sampling of urban respondents in the study design and analyses accounted for clustering of children within villages and sample stratification by district. We used Stata v12 (StataCorpLP; 4905 Lakeway Drive, College Station, TX, USA) for all analysis.

Results

Study population description

The final sample for this analysis included 4177 children under five years of age and their mothers. Among these, 469 (11.4 %) were underweight (Table 1). The relative frequencies of the seven anthropometric categories were distributed as follow: 33.87 % ($n = 1394$) were only stunted, 1.05 % ($n = 43$) only wasted, 0.43 % ($n = 17$) only underweight0.83 % ($n = 34$) underweight and wasted, 9.12 % ($n = 375$) underweight and stunted, 1.02 % ($n = 42$) were underweight, wasted and stunted, and the remaining 53.69 % ($n = 2210$) were neither underweight, stunted, nor wasted (Fig. 1). The overlapping categories mean that there are children who are at the same time underweight and wasted or stunted (a child may be too thin for his age and being too short compared to his age and weight). Boys and girls were equally represented and 638 (15.0 %) were reported to be small at birth. The majority of mothers ($n = 2255$, 54.0 %) were between ages 25 and 34 years, 755 (18.0 %) were under 24 years, and 1166 (28.0 %) were over 35 years. Most mothers ($n = 3016$, 72.0 %) had completed primary school, with 803

Fig. 1 Relative frequencies of 7 anthropometric categories
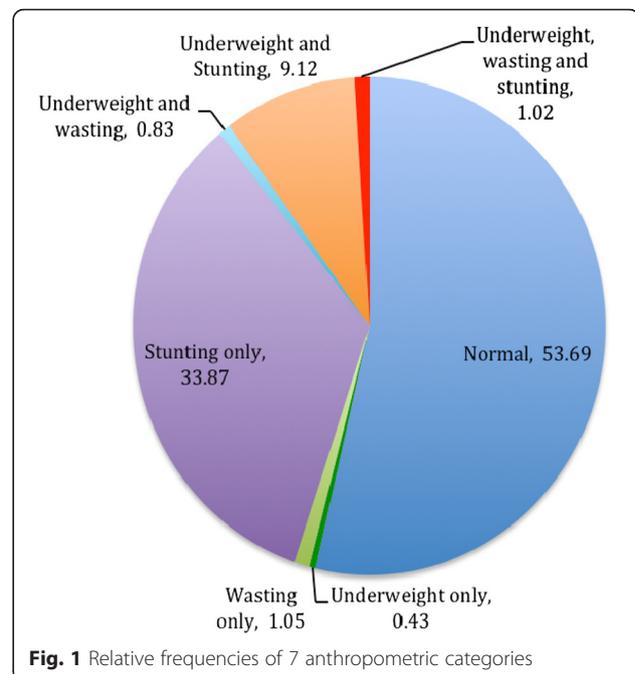
(19 %) having no education and 357 (9.0 %) having completed secondary school or higher. Few mothers ($n = 374$, 9.0 %) were skilled workers, 3385 (81.0 %) worked outside the home in an unskilled profession, and 415 (10.0 %) did not work outside the home. Household wealth was approximately evenly distributed across the quintiles; 1848 children (44.2 %) were from households in the bottom two wealth quintiles, 848 (20.0 %) were from households in the middle quintile, and 1480 (35.0 %) were from households in the top two wealth quintiles. Most children were from households in rural areas ($n = 3692$, 88.0 %). More than 50 % of households ($n = 2431$, 59.7 %) used improved toilets that were not shared, while the remainder had either unimproved or shared toilets. Over half of the children ($n = 2181$, 52.7 %) were from households from which it required at least 30 min to get water, 1787 (43.1 %) could access water in less than 30 min, and 167 (4.0 %) had water on premises. Half of households ($n = 2118$, 50.7 %) had access to improved water sources.

Univariable analysis of risk factors associated with underweight

The following child characteristics were associated with an increased risk of being underweight at the $p < 0.10$ level: male sex, fever in the previous two weeks, recent deworming treatment, time since the birth of the previous child and small size at birth. Mothers of underweight children were more likely to be over 35 years, to have lower education, to smoke, to be unskilled workers, to have a low BMI and to have had their last child

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Table 2 Univariable analysis of socio-demographic characteristics and underweight status in children under five in Rwanda, DHS 2010

	N weighted	Underweight %	Univariate OR [95 % CI]	p-value
Child characteristics				
Underweight	469	11.4	-	-
Child size at birth* age in months				
Not small size, <12	444	11.2	1	
Small size, <12	23	16.9	1.62 [0.97, 2.70]	0.067
Not small size, 12–23	442	11.1	1	
Small size, 12–23	25	19.6	1.95 [1.23, 3.10]	0.005
Not small size, 24–35	441	11.1	1	
Small size, 24–35	25	18.8	1.85 [1.18, 2.90]	0.008
Not small size, 36–47	444	11.1	1	
Small size, 36–47	22	19.6	1.95 [1.14, 3.33]	0.015
Not small size, 48–59	438	11.0	1	
Small size, 48–59	28	23.2	2.45 [1.60, 3.75]	<0.001
Child sex				
Girls	2075	10.0	1	
Boys	2101	12.7	1.31 [1.06, 1.60]	0.010
Breastfeeding				
Ever breastfed, not currently breastfeeding	2025	11.7	1	
Never breastfed	12	16.4	1.48 [0.36, 6.09]	0.586
Still breastfeeding	2123	11.0	0.94 [0.78, 1.13]	0.495
Fever in last 2 weeks				
No	3481	10.7	1	
Yes	693	14.7	1.43 [1.09, 1.86]	0.009
Deworming (drugs for intestinal parasites in last 6 months)				
No	897	9.3	1	
Yes	3278	12	1.33 [1.01, 1.76]	0.040
Diarrhea in last 2 weeks				
No	3606	11.0	1	
Yes	569	13.9	1.31 [1.00, 1.72]	0.052
Full vaccinated				
No	1029	10.2	1	
Yes	3147	11.8	1.18 [0.92, 1.52]	0.191
Birth interval (from previous birth)				
Singleton first-born	1014	6.8	1	
Singleton birth <2 years	624	8.4	1.26 [0.89, 1.80]	0.193
Singleton birth > =2 years	2437	13.2	2.09 [1.59, 2.76]	<0.001
Multiple births	101	31.2	6.21 [3.55, 10.85]	<0.001
Mother characteristics				
Mother age				
15–24 years	755	6.9	1	
25–34 years	2255	10.5	1.58 [1.09, 2.28]	0.015
35–49 years	1166	16.1	2.59 [1.79, 3.76]	<0.001

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Table 2 Univariable analysis of socio-demographic characteristics and underweight status in children under five in Rwanda, DHS 2010 *(Continued)*

Mother's highest level of educational				
No education	803	14.7	6.06 [3.22, 11.42]	<0.001
Primary	3016	11.5	4.60 [2.51, 8.43]	<0.001
Secondary or higher	357	2.8	1	
Smoking				
No	3988	11.1	1	
Yes	188	16.6	1.59 [1.00, 2.53]	0.049
Body mass index of mother				
< 18.5 underweight	186	24.5	2.52 [1.67, 3.81]	<0.001
18.5–24.9 normal weight	3000	11.4	1	
25.0–29.9 overweight	528	6.2	0.51 [0.35, 0.75]	0.001
> =30 Obesity	94	7.7	0.65 [0.31, 1.35]	0.245
Delivered by health care professional				
Yes	2919	9.9	1	
No	1257	14.8	1.57 [1.28, 1.94]	<0.001
Number of antenatal care visits				
None	53	10.1	1	
1	136	16.2	1.72 [0.61, 4.88]	0.306
2-3	1790	10.9	1.10 [0.43, 2.79]	0.843
4+	1084	9.6	0.95 [0.36, 2.46]	0.909
Mother occupation				
Not working	415	13.1	2.35 [1.33, 4.13]	0.003
Skilled worker	374	6.0	1	
Unskilled worker	3385	11.8	2.09 [1.33, 3.26]	0.001
Marital status				
Single	255	10.2	1	
Married	3573	11.0	1.09 [0.69, 1.75]	0.703
Divorced/separated	348	15.9	1.66 [0.96, 2.87]	0.068
Household characteristics				
Number of living children				
1-3	2547	9.5	1	
4+	1629	14.3	1.58 [1.27, 1.96]	<0.001
Number of persons in household				
2-3	599	7.8	1	
4+	3577	12.0	1.61 [1.17, 2.22]	0.004
Sex of the household head				
Female	877	11.8	1.05 [0.83, 1.33]	0.654
Male	3299	11.3	1	
Residence				
Urban	484	6.4	1	
Rural	3692	12.0	2.00 [1.35, 2.95]	0.001
Wealth quintiles				
Top 2	1480	7.4	1	
Middle	848	11.3	1.58 [1.15, 2.17]	0.004

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Table 2 Univariable analysis of socio-demographic characteristics and underweight status in children under five in Rwanda, DHS 2010 (Continued)

Bottom 2	1848	14.6	2.14 [1.66, 2.75]	<0.001
Toilet is clean upon inspection				
Yes	1442	8.7	1	
No	2717	12.8	1.53 [1.21, 1.94]	<0.001
Type of quality of toilet				
Unimproved shared	203	19.4	2.17 [1.43, 3.30]	<0.00
Improved shared	575	9.2	0.91 [0.62, 1.33]	0.635
Improved not shared	2431	10.0	1	
Unimproved not shared	866	15.0	1.60 [1.24, 2.07]	0.001
Proximity to improved water source				
Water on premise	167	5.5	1	
< 30 minutes	1787	11.9	2.31 [1.22, 4.38]	0.010
> =30 minutes	2181	11.6	2.26 [1.20, 4.28]	0.012
Anything done to water to make safe to drink				
Yes	2058	9.5	1	
No	2118	13.2	1.44 [1.15, 1.80]	0.001

*Women were asked, when the child was born "was he/she very large, larger than average, average, smaller than average, or very small?" We considered "smaller than average" and "very small" to be "small at birth" in this analysis

delivered by an unskilled provider. Households of underweight children were more likely to have more members, more children in the household, to be rural, to fall into a low wealth quintile, to have an unclean, unimproved, or shared toilet and to be 30 min or more from water. Breastfeeding, vaccination, antenatal care in the previous pregnancy, sex of the head of household and maternal marital status were not associated with underweight status (Table 2).

Risk factors associated with underweight, a multivariable analysis

In multivariable analysis, we found that children were more likely to be underweight if they were male (OR = 1.42, 95 % confidence interval (CI): 1.12, 1.79), had a fever in the two weeks prior to survey administration (OR = 1.45, 95 % CI: 1.07, 1.97) or were multiple birth infants compared to the first, single birth (OR = 4.04, 95 % CI: 2.12, 7.71). In an interaction analysis, we found that the effect of small size at birth persisted in all age strata. Children were also more likely to be underweight if their mothers were over 35 compared to those aged 17 to 24 (OR = 1.67, 95 % CI: 1.04, 2.70); had a BMI under 18.5 (OR = 2.62, 95 % CI: 1.70, 4.04); had either no education or primary education only (OR = 3.56, 95 % CI: 1.83, 6.95; OR = 3.49, 95 % CI: 1.87, 6.51, respectively) compared to secondary education or higher, or were attended by an unskilled provider during their last delivery (OR = 1.33, 95 % CI: 1.04, 1.72). Underweight children were more likely to live in households in one of the

two lowest wealth quintiles compared to the highest two quintiles (OR = 1.71, 95 % CI: 1.27, 2.30) (Table 3).

Discussion

In this analysis of the 2010 RDHS, we found that the prevalence of underweight children in Rwanda was low compared to the neighboring countries of Burundi, Democratic Republic of Congo and Tanzania [3], but considerably higher compared to the developed economies [11]. We identified several child risk factors for being underweight including being male, being small at birth, having fever in the two weeks prior to the survey and being born as a multiple birth infant. Maternal and household risk factors included the mother being 35 years or older, low education level, low maternal BMI, not having the delivery assisted by a health professional and wealth levels in the lowest two quintiles. While the prevalence of underweight children under five is lower in Rwanda compared to other countries in the region, many risk factors for under-nutrition among under five children are the same as those reported in nearby countries: these include fever, mother's nutritional status, mother's education level, household socio-economic status, and accessibility to piped water [8, 12–16]. Importantly, the persistent association between low maternal BMI and child under-nutrition in these studies suggests that intergenerational nutrition plays a strong role in these outcomes.

Among the child-related factors that were associated with being underweight, the only one that could potentially be addressed after a child's birth is recent febrile

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Table 3 Multivariable analysis of risk factors associated with being underweight among children under five in Rwanda, DHS 2010

	Full model		Reduced model	
	OR [95 % CI]	*p*-value	OR [95 % CI]	*p*-value
Child characteristics				
Size at birth* by age in months				
Normal, <12	1		1	
Small, <12	2.56 [1.40, 4.69]	0.002	2.38 [1.32, 4.28]	0.004
Not small size, 12–23	1		1	
Small size, 12–23	1.56 [0.84, 2.90]	0.161	1.36 [0.75, 2.47]	0.310
Not small size, 24–35	1		1	
Small size, 24–35	2.49 [1.39, 4.21]	0.002	2.46 [1.45, 4.19]	0.001
Not small size, 36–47	1		1	
Small size, 36–47	1.99 [1.01, 3.90]	0.045	2.16 [1.13, 4.15]	0.020
Not small size, 48–59	1		1	
Small size, 48–59	2.25 [1.29, 3.93]	0.004	2.27 [1.31, 3.94]	0.003
Sex				
Boys	1.42 [1.13, 1.79]	0.003	1.42 [1.12, 1.79]	0.002
Girls	1		1	
Fever in last 2 weeks				
No	1			
Yes	1.44 [1.05, 1.97]	0.023	1.45 [1.07, 1.97]	0.016
Received drugs for intestinal parasites in last 6 months				
No	1			
Yes	1.19 [0.82, 1.74]	0.365		
Diarrhea in previous 2 weeks				
No	1			
Yes	1.21 [0.86, 1.71]	0.274		
Birth interval (from previous birth)				
Singleton first-born	1		1	
Singleton birth <2 years	1.12 [0.71, 1.76]	0.622	1.17 [0.76, 1.82]	0.476
Singleton birth > =2 years	1.46 [0.95, 2.22]	0.082	1.69 [1.14, 2.51]	0.010
Multiple births	3.56 [1.84, 6.86]	<0.001	4.04 [2.12, 7.71]	<0.001
Mother characteristics				
Age				
15–24 years	1			
25–34 years	1.17 [0.73, 1.87]	0.506	1.17 [0.74, 1.84]	0.496
35–49 years	1.65 [0.97, 2.80]	0.066	1.67 [1.04, 2.70]	0.035
Highest level of educational				
No education	3.14 [1.61, 6.12]	0.001	3.56 [1.83, 6.95]	0.001
Primary	3.34 [1.78, 6.26]	<0.001	3.49 [1.87, 6.51]	<0.001
Secondary or higher	1		1	
Smoking				
No	1			
Yes	0.89 [0.53, 1.49]	0.649		

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Table 3 Multivariable analysis of risk factors associated with being underweight among children under five in Rwanda, DHS 2010 *(Continued)*

Body mass index				
< 18.5	2.80 [1.78, 4.40]	<0.001	2.62 [1.70, 4.04]	<0.001
18.5-24.9	1		1	
25.0-29.9	0.67 [0.45, 0.99]	0.046	0.66 [0.44, 0.98]	0.040
> =30	1.16 [0.55, 2.47]	0.695	0.99 [0.45, 2.16]	0.978
Delivered by health care professional				
Yes	1		1	
No	1.26 [0.97, 1.63]	0.080	1.33 [1.04, 1.72]	0.025
Occupation				
Not working	2.00 [1.03, 3.88]	0.041		
Skilled worker	1			
Unskilled worker	1.32 [0.74, 2.35]	0.340		
Marital status				
Single	1			
Married	1.06 [0.63, 1.80]	0.814		
Divorced/separated	1.68 [0.92, 3.08]	0.090		
Household characteristics				
Number of living children				
1–3	1			
4+	1.10 [0.82, 1.48]	0.517		
Number of persons in household				
2–3	1			
4+	1.54 [1.02, 2.32]	0.039		
Residence				
Urban	1			
Rural	1.11 [0.69, 1.78]	0.674		
Wealth quintiles				
Wealthiest (top two quintiles)	1			
Middle	1.25 [0.85, 1.82]	0.252	1.32 [0.92, 1.91]	0.131
Poorest (bottom two quintiles)	1.47 [1.06, 2.04]	0.020	1.71 [1.27, 2.30]	<0.001
Toilet is clean upon inspection				
No	1.09 [0.82, 1.45]	0.541		
Yes	1			
Type of quality of toilet				
Unimproved shared	1.81 [1.09, 3.03]	0.023		
Improved shared	1.06 [0.71, 1.60]	0.770		
Improved not shared	1			
Unimproved not shared	1.14 [0.83, 1.55]	0.412		
Proximity to improved water source				
Water on premise	1			
< 30 minutes	1.04 [0.47, 2.28]	0.926		
> =30 minutes	0.90 [0.41, 1.97]	0.788		

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Table 3 Multivariable analysis of risk factors associated with being underweight among children under five in Rwanda, DHS 2010 *(Continued)*

Anything done to water to make safe to drink		
Yes	1	
No	1.24 [0.97, 1.60]	0.088

*Women were asked, when the child was born "was he/she very large, larger than average, average, smaller than average, or very small?" We considered "smaller than average" and "very small" to be "small at birth" in this analysis

illness. The relationship between child nutrition and infection is bidirectional [17]. Being underweight increases the likelihood of febrile illness because malnutrition suppresses immunity to the culprit infectious agent [18]. Conversely, acute infection can lead to acute weight loss through increases in metabolic demand, impaired nutrient absorption or anorexia [3, 12]. Evidence exists in support of various interventions to improve malnutrition in children on the population-level, including increasing dietary intake following infection to hasten catch up growth [19–21] controlling infectious diseases [22, 23] and improving diets to prevent infection [22, 24]. However, given this cross-sectional study design, we cannot differentiate the direction of the relationship between underweight status and acute infection for the children included in this study. As such, the best interventions for tackling this vicious cycle of malnutrition and infection in Rwanda are unclear. A study based on data from 25 African DHSs found that non-singletons tend to be more malnourished than singletons [25]. Families with multiple births should be considered among the primary target for interventions designed to improve child nutrition [26].

Our finding that maternal education and nutritional status were correlated with a child's nutritional status is consistent with previous reports [16]. One previous study estimating contributions of different factors to the burden of under-nutrition attributed 43 % of the reduction in the prevalence of underweight children between 1970 and 2005 in developing countries to increases in women's secondary education [14]. Previous studies have shown that women with secondary education are better informed about optimal child care practices [8], have better practices in terms of hygiene [27, 28], feeding [18] and childcare during illness [18, 21, 22], have a greater ability to use the health system [29], are more empowered to make decisions [28] and are more likely to have financial resources to care for and feed children [18]. There has been a slight increase in the percentage of women who have completed secondary education in Rwanda, from 1.2 % in 2005 [30] to 2.8 % in 2010 [10], and we hypothesize that further gains in women's education may translate into improved child nutrition outcomes [7, 31, 32].

Although low maternal BMI has repeatedly been shown to be associated with poor child nutrition outcomes, it is unclear if this reflects the impact of poor nutrition on a mother's ability to care for her children or if it is the result of residual confounding by economic status [13].

Limitations
This study has several limitations that should be considered when interpreting the results. As this is a cross-sectional survey study, we are unable to draw causal conclusions about risk factors that lead to children being underweight. Although many of the associations we found are well established in literature and are biologically plausible, there is much less data on the impact of specific interventions designed to address these factors. In addition, some important factors were not measured in the DHS, including household food availability, which has been identified by UNICEF as an important determinant of child under-nutrition [3]. Also, even though underweight combines both stunting and wasting; underweight cannot show the extent to which a child is stunted or wasted, further analysis for risk factors associated with stunting and wasting may inform more the policy making.

Conclusion
Rwanda was one of the first countries to achieve MDG 1. However, even within Rwanda's context of rapid reduction, the prevalence of underweight children remains high. Several child risk factors for being underweight were identified, including being male, being small at birth, having fever in the two weeks prior to survey administration, and being born as a multiple. Maternal and household risk factors included the mother being 35 years or older, low maternal education level, low maternal BMI, not having the delivery assisted by a health professional and wealth levels in the lowest two quintiles. These risk factors highlight the characteristics of children who remain vulnerable to under-nutrition in Rwanda and who could benefit from both nutrition specific interventions such as Rwanda's one cup of milk per child program [33, 34], breastfeeding, complementary feeding, provision of food supplements, and micronutrient interventions [22] and nutrition sensitive interventions such as poverty reduction, social protections, women's empowerment, measures to boost agricultural production [35], social protection, and safety nets [24]. Because the impact of individual and combined interventions is not

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well established, we recommend that this should be studied to establish the contribution of each intervention and provide evidence for the most effective strategies.

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