Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged 6–36 months?

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Background: This study is the second to investigate the association between the use of biomass fuels (BMF) for household cooking and anaemia and stunting in children. Such fuels include coal, charcoal, wood, dung and crop residues.

Methods: Data from the 2006–2007 Swaziland Demographic and Health Survey (a cross-sectional study design) were analysed. Childhood stunting was ascertained through age and height, and anaemia through haemoglobin measurement. The association between BMF use and health outcomes was determined in multinomial logistic regression analyses. Various confounders were considered in the analyses.

Results: A total of 1150 children aged 6–36 months were included in the statistical analyses, of these 596 (51.8%) and 317 (27.6%) were anaemic and stunted, respectively. BMF use was not significantly associated with childhood anaemia in univariate analysis. Independent risk factors for childhood anaemia were child's age, history of diarrhoea and mother's anaemia status. No significant association was observed between BMF use and childhood stunting, after adjusting for child's gender, age, birth weight and preceding birth interval.

Conclusion: This study identified the need to prioritize anaemia and stunting as health outcomes and introduction of public health intervention in Swaziland. Further research is needed globally on the potential effects of BMF use on childhood anaemia and stunting.

Keywords: Anaemia, Biomass fuels, Indoor air pollution, Stunting, Swaziland, Demographic and Health Survey

Introduction

Half of the world's population still uses polluting fuels such as biomass fuels (BMF, which include coal, charcoal, wood, dung and crop residues) and paraffin (also known as kerosene) in inefficient stoves for cooking and space heating. Combustion of such fuels emits smoke that contains numerous air pollutants, such as PM_{10} (i.e. particulate matter smaller than 10 μm in diameter), $PM_{2.5}$, soot, nitrogen dioxide, sulphur dioxide and carbon monoxide (CO).[1]

Households that use BMF are often exposed to peak indoor PM_{10} levels that exceed the air quality guideline of 50 $\mu g/m^3$, according to the WHO.[1,2] Although the amount of exposure is dependent on the type of fuel used, the nature of the combustion, the location, the length of time individuals spend in the polluted environment and the composition of the smoke, women and children are the most vulnerable.[1,3] This is because women in developing countries are mainly responsible for cooking and child rearing; mothers carry infants and toddlers on their backs while cooking and expose them for many hours to inhaling polluting fuel smoke.[4]

Children exposed to BMF smoke are more vulnerable than their mothers as they breathe in more air per unit body weight at a given level of respiratory excursion than their mothers. Children exposed to BMF smoke have an increased risk of developing acute lower respiratory tract infections (ALRI) and even die as they do not yet have a fully developed respiratory and immune system.[5,6–10] Although BMF use has been associated with ALRIs and low birth weight,[11,12] little is known about its effects on childhood stunting and anaemia. No such study has ever been conducted in Swaziland.

Currently the mechanisms by which BMF use may contribute to anaemia and stunting are uncertain. BMF emits high CO levels, which bind with haemoglobin (required for transporting oxygen to body tissues), form carboxyhaemoglobin and reduce the level of haemoglobin in the blood, which leads to anaemia. CO levels in homes using BMF are occasionally high enough to result in carboxyhaemoglobin levels similar to those in tobacco smokers.[4,13] BMF smoke exposure can also contribute to stunting by causing not only anaemia but also reduced birth weight, ALRI and other childhood diseases.

Stunting is reduced height-for-age and is caused by a complex interaction between different social, economic and environmental factors. Tanner concluded that a strong relationship exists between children's height and socioeconomic status (SES) variables.[14] Apart from poor nutrition, children are vulnerable to other risks such as adverse home environments (e.g. polluting fuels for cooking), which negatively affect their development.[14] Similarly, anaemia is highly prevalent among children in many low-income countries.[15] Apart from the role of perinatal factors in contributing to childhood anaemia, previous research indicated that SES factors such as household overcrowding, number of children in the family, education and profession of the parents, source of drinking water, type of sewage system and child's health status are associated with childhood anaemia.[16]

Only one study also investigated the association between BMF household use, anaemia and stunting. Mishra and Retherford did a secondary data analysis of the 1998–1999 National Family Health Survey in India, that included 29 768 children aged 0–35 months from 92 486 households.[17] The researchers observed that the prevalence of moderate-to-severe anaemia was significantly higher among children in households using BMF exclusively for cooking and heating than among children in households using cleaner fuels (electricity, liquid petroleum gas, biogas or kerosene) exclusively (relative risk ratio[RRR] = 1.58, 95% CI 1.28–1.94), after adjusting for confounders such as environmental tobacco smoke, child's age and gender, recent episodes of illness, maternal education, maternal nutritional status and household living standard. The prevalence of severe stunting was also significantly higher among children in households that used BMF exclusively for cooking and heating (RRR = 1.84, 95% CI 1.44–2.36). Effects of BMF use for cooking and heating on mild anaemia and moderate stunting were smaller, but positive and statistically significant. The study also confirmed a strong positive association between anaemia and stunting in children.[17]

Detailed investigations into environmental factors that promote or suppress linear growth are necessary for a full understanding of the SES-related causes of anaemia and stunting. The current study used data from the 2006 − 2007 Swaziland Demographic Health Survey (SDHS) to investigate the association between BMF use for household cooking and stunting, and anaemia in children aged 6 − 36 months. Approximately 77% of the population of Swaziland lives in rural areas and 72% use wood fuel as their primary energy source for cooking and heating.[18] Wood, coal and charcoal in Swaziland are burnt mostly on open fires or in heavy iron coal stoves that have lower combustion efficiencies.[19] Despite plans for extensive rural electrification programmes in the country, it is clear that many rural and urban households will not convert to using electricity for cooking due to the unaffordable electricity connections and tariffs.[20] BMF therefore remain the most important fuel on a gross energy basis in both rural and urban households.

The 2000 Multiple Indicator Cluster Survey showed that 30% of Swazi children were stunted.[21] Swaziland is thus an ideal setting to study the relationship between BMF use and stunting because of the overlap in high BMF usage and high prevalence of stunting.

Materials and methods

Study design and location

The study had a cross-sectional design and applied secondary data collected in the 2006 − 2007 Swaziland Demographic and Health Survey (SDHS).[18] Swaziland is a developing country with a small population of about 1.4 million people and a population growth of 1.2% per annum. Swaziland ranks as a lower to middle-income country, but it is estimated that 69% of the population lives in poverty. The infant mortality rate is very high at 63 deaths per every 1000 live births and the current life expectancy is 48.7 years.

Study and target population and sampling

The 2006 − 2007 SDHS was a nationwide sample survey designed to provide information on various demographic, maternal and child health issues in Swaziland.[18] Fieldwork was conducted during July 2006 and April 2007.

The SDHS used multistage random sampling. The SDHS sample points (clusters) were selected from a list of enumeration areas (EA) defined in the 1997 Swaziland Population and Housing Census. A total of 275 clusters were drawn from the 1997 census sample frame comprising of 111 in urban areas and 164 in rural areas. The Central Statistics Office staff then conducted an exhaustive listing of households in each of the SDHS clusters and drew a systematic sample of 5500 households.

All women and men (aged 15 − 49 years) in the selected households were eligible for individual interviews. In addition, a subsample of half of these households (2750 households) was selected randomly in which all boys and girls aged 12 − 14 years (teenagers) and persons aged ≥50 years (elderly) were eligible for individual interviews. In the households where teenagers and the elderly were interviewed, all individuals (aged ≥6 months) were eligible for anaemia testing and all individuals (aged ≥2 years) were eligible for HIV testing.

In the households where only women and men (aged 15 − 49 years) were interviewed, children (aged 6 months to 5 years) were eligible for anaemia testing and women and men (aged 15 − 49 years) were eligible for anaemia and HIV testing. The final sample consisted of 4843 households, 4987 women (aged 15 − 49 years), 4156 men (aged 15 − 49 years) and 2812 children (aged <5 years); detailed information on the survey design is outlined elsewhere.[19]

Five types of questionnaires were used in the 2006 − 2007 SDHS, namely the household, women's, men's, youth and older adult questionnaires. The questionnaires were translated into the local SiSwati language.[18] Data collected with these questionnaires were obtained from the Demographic and Health surveys online archive at http://www.measuredhs.com/data/dataset/Swaziland_Standard-DHS_2006. The target population of the current study was children who were aged 6 − 36 months at the time of the fieldwork.

Health outcome variables

The women's questionnaire assessed the health status and risk factors of children. Anthropometric measurements (weight and height) and anaemia testing were recorded in the household questionnaire, as was the information on all the usual members and visitors in the selected households and the consent of eligible household members for the HIV testing. The women's questionnaire assessed other health outcomes and risk factors of children.

The anaemia status of children and their biological mothers were determined with the portable HemoCue system (Kuvettgatan, Angelholm, Sweden).[18] The system uses a drop of blood from a fingerprick (or heel prick for infants aged <6 months),

which is drawn into a cuvette and then inserted into a portable battery-operated instrument to obtain a digital reading on the haemoglobin concentration. Children were categorized as not anaemic (≥11.0 g/dL), mildly anaemic (10.0–10.9 g/dL), moderately anaemic (7.0–9.9 g/dL) and severely anaemic (<7.0 g/dL).[19] Because the proportion of severely anaemic children was small (<5%) in the study population, a three-category response variable for anaemia was used: not anaemic, mildly anaemic and moderately/severely anaemic.[22]

Height measurements were conducted with a measuring board produced by Shorr Productions (Olney, MD, USA**)**. Children aged <24 months were measured while lying down (recumbent length) on the board and children aged ≥24 months while standing up.[18] Children were categorized as mildly stunted if their height-for-age ratio was 2–3 SDs below the median of the WHO reference population in terms of height-for-age and severely stunted if their height-for age-ratio was below <3 SD from the median of the WHO reference population.[23]

Exposure variable

The main exposure variable 'BMF use for household cooking' was ascertained in the household questionnaire, 'What fuel does your household mainly use for cooking?', as done in other studies.[24] The households were grouped into two categories: 'Cleaner fuel use' if liquid petroleum gas/natural gas, electricity and/or paraffin was used exclusively; and 'BMF use' if either coal, charcoal and/or wood were used with or without the cleaner fuels in the fuel combination.

Potential confounders

The association between BMF use, anaemia and stunting is likely to be confounded by childhood, maternal and household factors (Box 1).

Statistical analysis

Analyses were performed using STATA 11 (StataCorp. Ltd, College Station, TX, USA). The total number of children (aged >5 years) included in the 2006 − 2007 SDHS was 2812.[18] The following exclusions were made in the statistical analyses: children who were aged <6 months and those who were aged >36 months; children who did not live with the questionnaire respondent; children who were deceased; children who were visitors at the time of the survey; children from multiple births; and children whose height measurements were missing. In total 1662 children were excluded, leaving a sample size of 1150 children in this investigation.

The associations (RRRs) between the two health outcomes, the main exposure variable and the childhood, maternal and household factors were first assessed in univariate multinomial logistic regression models. Factors that were significantly associated at the 95% confidence level ($p < 0.05$) with the two health outcomes were included in the multivariate multinomial logistic regression analyses. The estimation of 95% CIs was used to adjust for clustering at the level of the primary sampling unit.

Box 1. Potential confounders grouped by childhood, maternal and household factors

Childhood factors[a]

- Gender (boy, girl)
- Age (6 − 11, 12 − 23, 24 − 36 months)
- Birth order (1, 2, 3, ≥4)
- Preceding birth interval (<24 months, ≥24 months)
- Birth weight (<2500 g, ≥2500 g)
- Recent episodes of acute lower respiratory tract infection in past 2 weeks (yes/no)
- Recent episodes of fever in past 2 weeks (yes/no)
- Recent episodes of diarrhoea in past 2 weeks (yes/no)

Maternal factors

- Age at the child's birth (<18, 18–24, 25–34, ≥35 years)
- Body mass index at the time of the SDHS (<18.5, 18.5–25.0, >25.0 kg/m^2)
- Highest educational status at the time of the SDHS (no education, primary, secondary, tertiary),
- Iron supplementation during pregnancy (no/yes)
- Anaemia status at the time of the SDHS (mild anaemia: blood haemoglobin level 10.0–10.9 g/dL for pregnant women and 10.0–11.9 g/dL for non-pregnant women; moderate anaemia: blood haemoglobin level 7.0–9.9 g/dL; severe anaemia: blood haemoglobin level <7.0 g/dL)

Household factors

- Household location at the time of the SDHS (urban/rural),
- Region of household at the time of the SDHS (Hlohlo, Shesweleni, Lubombo, Manzini)
- Crowding at the time of the SDHS (<3 persons/room, ≥3 persons/room)
- Wealth index at the time of the SDHS (low, middle, high)[b]

SDHS: Swaziland Demographic and Health Survey, 2006 − 2007.[18]
[a]The child's anaemia status at the time of the SDHS (none, mild, moderate/severe) was also a potential risk factor for stunting.
[b]The wealth quintiles in the SDHS were used and then grouped into three categories: high, medium and low.[18]

Results

Description of the study sample

The sample comprised 1150 children aged 6 − 36 months with an almost equal proportion of boys 51.1% (n = 588) and girls 48.9% (n = 562). The majority 76.1% (n = 875) were from rural households and 73.0% (n = 840) came from households whose main cooking fuel was BMF. Overall, 596 (51.8%) children were anaemic; 271 (23.6%) were mildly anaemic and 325 (28.3%) were severely anaemic. Three hundred and seventeen (27.6%) children were stunted; 194 (16.9%) were mildly stunted and 123 (10.7%) were severely stunted (Table 1). There was a statistically significant difference in the proportion of rural vs urban households

Table 1. Sample distribution of 1150 Swazi children, aged 6 – 36 months, by selected characteristics during July 2006 and April 2007

Characteristic	Total (%)	BMF use[a]	No BMF use[a]
Child's anaemia status			
Normal	554 (48.2)	413	122
Mild	271 (23.6)	193	74
Moderate/severe	325 (28.3)	234	79
Child stunting			
Normal	833 (72.4)	593	218
Mild	194 (16.9)	150	36
Severe	123 (10.7)	97	21
Main type of household cooking fuel			
Electric	114 (9.9)	0	114
Natural gas	121 (10.5)	0	121
Paraffin	40 (3.5)	0	40
Coal	3 (0.3)	3	0
Charcoal	9 (0.8)	9	0
Wood	828 (72.0)	828	0
Missing data	35 (3.0)	–	–
BMF used for cooking			
No	275 (23.9)	0	275
Yes	840 (73.0)	840	0
Missing	35 (3.0)	–	–
Have electricity in household			
No	849 (73.8)	740	107
Yes	268 (23.3)	100	168
Missing data	33 (2.9)	–	–
Child's gender			
Male	588 (51.1)	439	131
Female	562 (48.9)	401	144
Child's age (months)			
6 – 11	279 (24.3)	195	76
12 – 23	479 (41.7)	350	113
24 – 36	392 (34.1)	295	86
Child's birth order			
1	373 (32.4)	268	87
2	257 (22.3)	172	78
3	168 (14.6)	114	50
≥ 4	352 (30.6)	286	60
Child's birth weight (g)			
< 2500	73 (6.3)	47	23
≥ 2500	1077 (93.7)	793	252
Child's preceding birth interval (months)			
≤ 24	349 (30.3)	270	66
> 24	801 (69.7)	570	209
Child had acute respiratory illness in past 2 weeks			
No	954 (83.0)	684	241
Yes	196 (17.0)	156	34
Child had fever in past 2 weeks			
No	732 (63.7)	526	182
Yes	410 (35.7)	309	91
Missing	8 (0.7)	–	–
Child had diarrhoea in past 2 weeks			
No	897 (78.0)	650	216

Continued

Table 1. *Continued*

Characteristic	Total (%)	BMF use[a]	No BMF use[a]
Yes	253 (22.0)	190	59
Mother's age at child's birth (years)			
< 25	621 (54.0)	469	128
≥ 25	529 (46.0)	371	147
Mother's anaemia status			
Normal	883 (76.7)	654	201
Mild	209 (18.1)	140	62
Moderate/severe	58 (5.0)	46	12
Mother's iron supplementation during pregnancy			
No	133 (11.6)	101	22
Yes	901 (78.4)	650	229
Missing data	116 (10.0)	–	–
Mother's body mass index (kg/m^2)			
< 18.5	26 (2.3)	15	10
18.5–25.0	532 (46.3)	404	112
> 25.0	592 (51.5)	421	153
Mother's highest educational attainment			
No education	96 (8.3)	82	12
Primary education	433 (37.7)	360	57
Secondary education	559 (48.6)	391	153
Higher education	62 (5.4)	7	53
Household crowding (people/room)			
< 3	490 (42.6)	324	153
≥ 3	660 (57.4)	516	122
Household wealth index			
Middle and lower	751 (65.3)	690	44
High	399 (34.7)	150	231
Household's area			
Urban	240 (20.9)	57	183
Rural	875 (76.1)	783	92
Missing	35 (3.0)	–	–
Household's region			
Hhohho	274 (23.8)	195	73
Manzini	323 (28.1)	214	102
Shiselwe	274 (23.8)	227	38
Lubombo	279 (24.3)	204	62

–: BMF use was not assessed due to missing data.
[a]Numbers may not add up to the total for the characteristic due to 35 missing observations for the BMF use variable.

using BMF: 89.5% (783/875) of rural households used BMF for cooking compared with 23.8% (57/240) of urban households ($p < 0.001$). Use of BMF was significantly higher in households of low wealth index (91.9%; 690/751) compared with middle to high wealth index homes (37.6%; 150/399) ($p < 0.001$). There was no statistically significant difference in the proportion of children living in rural or urban areas by age, gender and birth weight.

Univariate analyses

BMF use for cooking was not associated with anaemia in children. Statistically significant associations were observed between severe anaemia in children and being aged 24–36 months (RRR = 0.3, 95% CI 0.2–0.5; $p < 0.001$), history of childhood diarrhoea in past 2 weeks (RRR = 2.1, 95% CI 1.5–2.9; $p < 0.001$), mother's mild anaemia status (RRR = 2.0, 95% CI 1.4–2.9; $p < 0.001$) and mother's moderate-to-severe anaemia status (RRR = 2.4, 95% CI 1.1–5.2; $p = 0.023$) (Table 2). Mild anaemia in children was associated with history of childhood diarrhoea in past 2 weeks (RRR = 1.5, 95% CI 1.0–2.3; $p = 0.041$), mother's mild anaemia status (RRR = 2.0, 95% CI 1.4–3.1; $p < 0.001$) and mother's moderate-to-severe anaemia status (RRR = 2.3, 95% CI 1.0–5.3; $p = 0.039$).

There was a statistically significant difference in the prevalence of mild stunting in children by exposure to BMF use (RRR = 1.6, 95% CI 1.0–2.5; $p = 0.037$), being aged 12–23 months (RRR = 2.9, 95%

Table 2. Crude relative risk ratio (RRR) estimates of household cooking fuel type and other risk factors for stunting and anaemia among 1150 Swazi children (6 − 36 months) during July 2006 and April 2007

Characteristic	Stunting		Anaemia	
	Mild RRR (95% CI)	Severe RRR (95% CI)	Mild RRR (95% CI)	Moderate/severe RRR (95% CI)
BMF used for cooking				
No	1	1	1	1
Yes	1.6 (1.0–2.5)*	1.5 (0.9–2.6)	0.8 (0.5–1.1)	0.8 (0.6–1.2)
Child's anaemia status				
Normal	1	1	–	–
Mild	0.9 (0.6–1.4)	1.4 (0.9–2.2)	–	–
Moderate/severe	1.1 (0.8–1.6)	1.4 (0.9–2.2)	–	–
Child's gender				
Male	1	1	1	1
Female	0.7 (0.5–1.0)	0.6 (0.4–0.9)*	1.0 (0.8–1.3)	1.0 (0.7–1.3)
Child's age (months)				
6 − 11	1	1	1	1
12 − 23	2.9 (1.7–5.1)*	2.4 (1.4–4.2)*	1.1 (0.8–1.7)	1.3 (0.9–1.9)
24 − 36	3.2 (1.8–5.7)*	1.6 (0.9–2.7)	0.7 (0.5–1.0)	0.3 (0.2–0.5)*
Child's birth order				
1	1	1	1	1
2	1.3 (0.9–2.0)	0.8 (0.5–1.4)	0.9 (0.6–1.4)	1.0 (0.7–1.5)
3	0.5 (0.3–1.0)	0.6 (0.3–1.2)	1.0 (0.6–1.6)	1.0 (0.6–1.5)
≥ 4	1.2 (0.8–1.9)	1.0 (0.6–1.6)	0.9 (0.6–1.4)	0.9 (0.7–1.3)
Child's birth weight (g)				
< 2500	1	1	1	1
≥ 2500	0.5 (0.3–0.9)*	0.4 (0.2–0.7)*	1.1 (0.6–2.1)	0.8 (0.5–1.2)
Child's preceding birth interval (months)				
≤ 24	1	1	1	1
> 24	0.7 (0.5–0.9)*	0.8 (0.5–1.3)	1.2 (0.8–1.7)	1.2 (0.8–1.6)
Child had acute respiratory illness in past 2 weeks				
No	1	1	1	1
Yes	0.9 (0.6–1.4)	0.7 (0.4–1.2)	1.3 (0.8–1.9)	1.4 (1.0–2.1)
Child had fever in past 2 weeks				
No	1	1	1	1
Yes	1.0 (0.7–1.4)	1.0 (0.7–1.5)	1.3 (0.9–1.9)	1.5 (1.1–2.0)
Child had diarrhoea in past 2 weeks				
No	1	1	1	1
Yes	1.0 (0.7–1.4)	1.2 (0.7–1.8)	1.5 (1.0–2.3)*	2.1 (1.5–2.9)*
Mother's age at child's birth (years)				
< 25	1	1	1	1
≥ 25	0.8 (0.6–1.1)	0.6 (0.4–1.0)	0.9 (0.7–1.2)	0.8 (0.6–1.1)
Mother's anaemia status				
Normal	1	1	1	1
Mild	0.9 (0.6–1.3)	1.2 (0.7–2.1)	2.0 (1.4–3.1)*	2.0 (1.4–2.9)*
Moderate/severe	0.9 (0.4–1.9)	1.7 (0.8–3.7)	2.3 (1.0–5.3)*	2.4 (1.1–5.2)*
Mother's iron supplementation during pregnancy				
No	1	1	1	1
Yes	0.7 (0.4–1.2)	0.8 (0.4–1.5)	1.4 (0.9–2.2)	1.0 (0.7–1.6)
Mother's body mass index (kg/m^2)				
< 18.5	1	1	1	1
18.5–25.0	0.8 (0.3–2.3)	0.5 (0.2–1.3)	0.8 (0.3–2.2)	1.1 (0.4–3.1)

Continued

Table 2. *Continued*

Characteristic	Stunting		Anaemia	
	Mild RRR (95% CI)	Severe RRR (95% CI)	Mild RRR (95% CI)	Moderate/severe RRR (95% CI)
> 25.0	0.7 (0.2–2.2)	0.5 (0.2–1.5)	0.6 (0.2–1.6)	0.7 (0.3–2.1)
Mother's highest educational attainment				
No and primary education	1	1	1	1
Secondary and higher education	0.7 (0.5–1.0)	0.7 (0.5–1.0)	1.1 (0.8–1.6)	1.0 (0.7–1.3)
Household crowding (people/room)				
< 3	1	1	1	1
≥ 3	1.0 (0.7–1.4)	1.2 (0.8–1.7)	1.2 (0.9–1.6)	1.3 (1.0–1.7)
Household wealth index				
Middle and lower	1	1	1	1
High	0.7 (0.4–0.9)*	0.7 (0.5–1.2)	1.0 (0.7–1.5)	1.0 (0.7–1.3)

*$p < 0.05$.
Models were stratified by household's region.

Table 3. Adjusted relative risk ratio (RRR) estimates of household cooking fuel type and other risk factors for stunting among 1150 Swazi children, aged 6 − 36 months, during July 2006 and April 2007

Characteristic	Mild stunting RRR (95% CI)	Severe stunting RRR (95% CI)
BMF used for cooking		
No	1	1
Yes	1.1 (0.6–2.0)	1.4 (0.7–2.7)
Child's gender		
Male	1	1
Female	0.7 (0.5–0.9)*	0.6 (0.4–0.9)*
Child's age (months)		
6 − 11	1	1
12 − 23	3.0 (1.7–5.3)*	2.5 (1.4–4.5)*
24 − 36	3.1 (1.7–5.6)*	1.7 (1.0–2.9)
Child's birth weight (g)		
< 2500	1	1
≥ 2500	0.3 (0.2–0.6)*	0.3 (0.2–0.6)*
Child's preceding birth interval (months)		
≤ 24	1	1
> 24	0.7 (0.5–1.0)*	0.7 (0.5–1.2)
Household wealth index		
Middle and lower	1	1
High	0.6 (0.4–1.1)	0.9 (0.5–1.5)

*$p < 0.05$.
Models were stratified by household's region.

CI 1.7–5.1; $p < 0.001$), being aged 24–36 months (RRR = 3.2, 95% CI 1.8–5.7; $p < 0.001$), child's normal birth weight (RRR = 0.5, 95% CI 0.3–0,9; $p = 0.021$), preceding birth interval <24 months (RRR = 0.7, 95% CI 0.5–0.9; $p = 0.014$) and higher household wealth index (RRR = 0.7, 95% CI 0.4–0.9; $p = 0.026$). There was a statistically significant difference in the prevalence of severe stunting in children by child gender (RRR = 0.6, 95% CI 0.4–0.9; $p = 0.007$), child being aged 12–23 months (RRR = 2.4, 95% CI 1.4–4.2; $p = 0.002$) and child's birth weight (RRR = 0.4, 95% CI 0.2–0.7; $p = 0.002$) (Table 1).

Multivariate analyses

The association between BMF use for household cooking and stunting was weaker and not statistically significant after adjusting for potential confounders. Only female gender (RRR = 0.7, 95% CI 0.5–0.9; $p = 0.021$), child being aged 12–23 months (RRR = 3.0, 95% CI 1.7–5.3; $p < 0.001$), child being aged 24–36 months (RRR = 3.1, 95% CI 1.7–5.6; $p < 0.001$), birth weight (RRR = 0.3, 95% CI 0.2–0.6; $p = 0.001$), and preceding birth interval >24 months (RRR = 0.7, 95% CI 0.5–1.0; $p = 0.026$) were significantly associated with mild stunting. Female gender (RRR = 0.6, 95% CI 0.4–0.9; $p = 0.013$), child being aged 12–23 months (RRR = 2.5, 95% CI 1.4–4.5; $p = 0.002$) and birth weight (RRR = 0.3, 95% CI 0.2–0.6; $p = 0.001$) were significantly associated with severe stunting. Girls were less likely to be stunted compared with boys. Children aged >12 months were more likely to be stunted when compared with the youngest age group. Children with normal birth weight were less likely to be stunted compared with those with a low birth weight. Children born more than 2 years apart were less likely to be stunted (Table 3).

Discussion

The study confirms a high prevalence of BMF use for cooking among households and a high prevalence of anaemia and stunting in

children aged 6 − 36 months in Swaziland. An association between BMF use and childhood stunting was observed in univariate analysis. Even though the findings were not significant in multivariate analysis, they were similar to findings of other studies done in other low-income countries.[12, 25, 26]

In this study, one of the independent risk factors for childhood anaemia was the mother's anaemia status. A dose–response relationship between mother's and child's anaemia status was observed, with the highest risk of anaemia in children among mothers with moderate-to-severe anaemia. These findings are consistent with previous reports[27,28] suggesting that interventions to prevent anaemia in children aged <3 years should include the prevention of anaemia during pregnancy.

Another independent risk factor for childhood anaemia was history of diarrhoea in the past 2 weeks. This could be as a result of poor absorption of micronutrients due to inflammation of the bowels or the presence of intestinal helminths.[29,30] In addition, acute diarrhoea in children under five could be precipitated by an episode of malarial parasitaemia, a common cause of childhood anaemia in developing countries.[31]

Contrary to the Mishra and Retherford study,[17] our study showed that girls had a significantly lower risk of stunting compared with boys. This is consistent with other studies conducted in sub-Saharan Africa and Asia.[32,33] Based on these findings it is worthwhile investigating gender-related differences in childcare or feeding patterns in Swaziland. Children aged >12 months were more at risk of stunting and anaemia compared with the youngest age group. The reason could be that the younger age group is probably still being breastfed hence their nutritional status may not have been compromised. These findings are consistent with cross-sectional studies from other developing countries.[33–35]

Findings of a 3-year longitudinal survey conducted in Cameroon reported an age-related decrease in the prevalence of anaemia in children aged 6 − 60 months.[36] Other studies from Pakistan,[3], Kenya[38] and Ethiopia[39,40] and reported similar findings. Our observations provide further evidence in support of public health interventions to reduce stunting and anaemia in children aged <3 years. In addition to the above, children born with normal birth weight were less likely to have stunted growth compared with those born with low birth weight, which is biologically plausible and consistent with other research findings.[41–43]

Limitations

There are some important limitations that need to be taken into account when interpreting the results of this study. The SDHS had a cross-sectional design and an inherent limitation of this epidemiological study design type is the inability to prove causation, since health status and determinants are measured simultaneously. Reliance on self-reported data does include a risk of misclassification of disease and exposure status resulting in statistical significance arising by chance. Information on the confounding factors is based on mothers' reports and there is possibility of recall bias. Exposure to BMF smoke was ascertained indirectly from type of fuel used for household cooking and there is a possibility of non-differential exposure misclassification, which may have underestimated the association between BMF use and the health outcomes.

BMF is also used for heating purposes during colder months, a common practice in developing countries such as Swaziland. The combustion of BMF for heating is done over a longer time period than for cooking. This additional use of BMF was not ascertained in the SHDS. In future SDHS it is imperative to include a question on the type of fuels used for space heating purposes.

There are other factors that may contribute to childhood anaemia and stunting that were not recorded in the SDHS, e.g. outdoor and other indoor air pollution sources (i.e. mothers smoking status, location of household in close proximity to industries, transport services, insecticide or fertiliser use, waste fill sites, dust), access to medical services, mother's pre-pregnancy weight, poor nutritional status, and intestinal helminth, malaria and HIV infection. These are important risk factors and excluding them from the analysis may have led to an underestimation of the observed effects (differential or non-differential misclassification). Not every household member that participated in the survey was tested for HIV, hence we could not adjust for this important confounder.

Nevertheless, this is the first study to investigate the association between BMF use, anaemia and stunting in children in Sub-Saharan Africa. In addition, the main health outcomes of this the study (anaemia and stunting) were measured directly. In epidemiological studies, the generalizability of data is determined by the response rate. The response rate of the SDHS was >90% for both the household and woman's health surveys hence minimal likelihood that bias in this study could be due to non-response.

Conclusion

The study observed a high prevalence of anaemic and stunted children in the Swazi population. Further research, e.g. use of prospective epidemiological design, on the relationship between indoor BMF smoke exposure and anaemia and stunting is advisable. Programmes or interventions aimed at reducing childhood stunting and anaemia should specifically target boys and other children aged <3 years. In addition, other interventions should focus on reducing incidence of diarrhoea, low birth weight and anaemia in pregnant women.

Authors' contributions: JW conceived the study; MM designed the study, analysed and interpreted data, and drafted the manuscript; JW and PSN critically reviewed the manuscript for intellectual content and structured writing. All authors read and approved the final version of manuscript. PSN is guarantor of the paper.

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