# Exploring determinants of under-5 stunting in Malawi using a generalised linear mixed model

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**Background.** Although several studies have examined determinants of stunting, most fail to account for unobserved heterogeneity in clustered survey data.
**Objective.** To investigate the determinants of stunting among Malawian children under-5 years of age.
**Methods.** The study utilised cross-sectional data on 5 686 children aged 0 - 59 months extracted from the 2015 - 2016 Malawi Demographic and Health Survey dataset. Data were analysed using a generalised linear mixed model applied to clustered data.
**Results.** Children who were female (adjusted odds ratio (aOR) 0.83; 95% confidence interval (CI) 0.73 - 0.94), from wealthier households (aOR 0.68; CI 0.58 - 0.81), and whose mothers were overweight/obese (aOR 0.78; CI 0.65 - 0.94), aged 25 - 34 years (aOR 0.76; CI 0.62 - 0.93) or had at least a secondary level education (aOR 0.73; CI 0.56 - 0.94) were less likely to be stunted. The likelihood of stunting was higher among children who were anaemic (aOR 1.38; CI 1.20 - 1.59) and in whom respondents reported small birth size (aOR 1.61; CI 1.34 - 1.93). Age ≥12 months, being a twin or triplet and living in the Central region of Malawi also increased a child's risk of being stunted. About 3.0% of the variance in likelihood of being stunted occurred across communities (clusters).
**Conclusions.** Hidden community variations of child stunting in clustered-survey data need to be accounted for. Stunting strategies should be context specific.

Stunting is a risk factor for poor health and psychosocial development arising from *in utero* and/or early childhood malnutrition.[1] As the most prevalent form of child malnutrition, stunting remains a public health problem.[2] Although efforts have been put in place by various stakeholders to ameliorate these negative impacts through several nutrition interventions,[1,3,4] reduction in the trend of malnutrition in under-5-year-olds (hereafter 'under-5 malnutrition') in Malawi and many sub-Saharan African countries is still suboptimal. Worryingly, the 2015 - 2016 Malawi Demographic Health Survey (MDHS) reported a prevalence of 37.1% stunting in under-5s.[5]

Previous studies have used varying statistical approaches to examine factors associated with stunting in Malawi,[6-9] in other sub-Saharan African countries[10-13] and elsewhere.[14-16] These studies attest to individual setting or country peculiarities and the multifaceted nature of the associated risk factors. In Malawi, the likes of quantile regression,[6] linear random effect model,[17] generalised estimating equation,[9] logistic regression,[7,18] and multilevel logistic regression model[8] have been employed to identify determinants of stunting. Many of these studies, however, do not account for unobserved heterogeneity in clustered-survey data.

We sought to identify potential risk factors of stunting among under-5s in Malawi using a generalised linear mixed model (GLMM) approach. The GLMM was employed to appropriately adjust for the peculiar nature of hierarchical data, including missing observation, using the most recent MDHS clustered dataset. This was necessary to attain objective and unbiased inferences on predictors of child stunting.

## Methods

### Study design, setting and population
The present analysis used the 2015-16 MDHS data, a cross-sectional design aimed at providing population and maternal-and-child-health indicators.[5] Ethical approval for the parent study was obtained from the National Health Sciences Research Committee, Malawi. The Demographic and Health Surveys Program approved the use of the dataset for the present analysis.

Malawi has a population of 18.1 million, of whom 2.9 million were under 5 years of age in 2016. Only 16% of the population resided in urban areas.[4,5] The multistage cluster sampling technique was used for the survey, based on the sampling frame containing enumeration areas (EAs), adopted from the 2008 Malawi Population and Housing Census. At the first stage, 850 EAs referred to as clusters (communities) were selected as the primary sampling units. A total of 26 361 of the sampled households within the selected EAs were interviewed at the second stage. The detailed sampling procedure has been reported previously.[5]

Of 6 033 under-5s eligible for anthropometric measurement within households, 5 686 (94%) had complete and valid height measurements.[5] The term 'cluster' is used interchangeably with 'community' to indicate children living in the same household within the same geographical location in this study.

### Study variables
The outcome of interest is the stunting of under-5s measured by height-for-age. With the use of a ShorrBoard measuring board (Shorr Productions, USA), length of children aged <24 months was

measured supine and those aged ≥24 months were measured while standing. The height-for-age variable was transformed into a binary variable (stunting present or absent) depending on whether a child's $z$-score was below or above −2 standard deviations (SDs) from the median of the World Health Organization (WHO) reference population.[5] The independent variables included to define child, maternal and household characteristics are presented in Appendix 1 (http://www.sajch.org.za/public/files/1756.pdf).

## Statistical methods of analysis

Descriptive statistics and GLMM with a binomial random distribution and logit link function were used for the analysis. Besides the use of GLMM at a bivariate level to identify individual explanatory variables' influence on child stunting, GLMM was further used to identify determinants of stunting among under-5s using a 4-stage approach at multivariate level. Models 1, 2 and 3 respectively included variables to define child, maternal and household characteristics, irrespective of their significance status at the bivariate level. Thereafter, significant predictors (having 95% confidence intervals (CIs) not including 1) from models 1 - 3 were included in final model 4. The odds ratios (OR) and their CIs are reported. The intra-community correlation coefficient (ICC) that measures the proportion of variance explained by clustering in hierarchical data is reported. An ICC ≥2% implies existence of a significant cluster level effect which calls for a multilevel approach.[19,20] Akaike information criteria (AIC) values are also reported for model comparison; the model with the lowest value was adjudged as being more adequate.[21,22] All analyses were carried out at 5% level of significance, using STATA 14 SE (StataCorp., USA).

## Model description

The GLMM is an extension of generalised linear models which takes into consideration all contextual (level-two) information.[23] The model specifically combines and estimates both the fixed- and random-effects appropriate for clustered data. The model could be briefly described as follows.

Let $Y_{ij}$ be the stunting status of $i^{th}$ under-5 in $j^{th}$ cluster defined as

$$Y = \begin{cases} 1, & \text{stunted (with probability } \pi) \\ 0, & \text{otherwise (with probability } 1\text{-}\pi) \end{cases}$$  Equation 1

For  $E(Y = 1/X_{ij}, \varphi_j, \varepsilon_j) = \pi$  Equation 2

the GLMM can be described as follows.

$$y_{ij} = log_e\left(\frac{\pi}{1-\pi}\right) = \beta_p x_{ijp} + \theta_r \varphi_{rj} + \varepsilon_j$$  Equation 3

where

$$\pi = Pr(Y = 1/X_{ij}, \varphi_j, \varepsilon_j) = \frac{e^{\beta_p x_{ijp} + \theta_r \varphi_{rj} + \varepsilon_j}}{1 + e^{\beta_p x_{ijp} + \theta_r \varphi_{rj} + \varepsilon_j}}$$  Equation 4

Level-one p-variable is represented by $xijp$ (varies within and between clusters); level-two r-variable is represented by $\phi rj$ (varies only between clusters); and the random intercept is $ej$.

The four-stage random intercept model approach adopted was subject to the grouping of explanatory variables into child, maternal and household characteristics. In model 1, simultaneous effects of child's age, sex, birth size, birth type, birth interval, anaemia status and recent illness on stunting were estimated. While model 2 includes mother's age, education, body mass index (BMI), marital status, employment, number of living children and breastfeeding status, model 3 simultaneously estimates the effect of regions,

**Table 1. Percentage distribution and prevalence of under-5 stunting according to child, maternal and household characteristics**

| Characteristics | $n$ (%) | Stunted, % |
|---|---|---|
| *Child, N=5 686* | | |
| Child age (mo.) | | |
| <12 | 1 082 (19.0) | 23.3 |
| 12 - 23 | 1 088 (19.1) | 38.8 |
| >23 | 3 516 (61.8) | 40.9 |
| Sex | | |
| Male | 2 761 (48.6) | 39.0 |
| Female | 2 925 (51.4) | 35.4 |
| Birth size* | | |
| Average | 2 522 (49.6) | 35.9 |
| Small | 821 (16.2) | 47.3 |
| Large | 1 743 (34.3) | 32.7 |
| Birth order* | | |
| 1st | 1 267 (24.7) | 36.3 |
| 2nd to 4th | 2 652 (51.7) | 35.4 |
| >4th | 1 210 (23.6) | 39.1 |
| Birth type* | | |
| Singleton | 4 977 (97.0) | 35.8 |
| Multiple | 152 (3.0) | 61.1 |
| Birth interval* | | |
| First birth | 1 268 (24.8) | 36.3 |
| <24 | 374 (7.3) | 44.4 |
| 24 - 47 | 2 034 (39.7) | 36.8 |
| ≥48 | 1 442 (28.2) | 34.1 |
| Anaemiac* | | |
| No | 1 915 (37.4) | 34.7 |
| Yes | 3 206 (62.6) | 40.8 |
| Recent illness* | | |
| No | 2 505 (49.0) | 37.3 |
| Yes | 2 608 (51.0) | 35.7 |
| *Maternal (N=5 129)* | | |
| Mother age (y)* | | |
| 15 - 24 | 1 881 (36.7) | 38.5 |
| 25 - 34 | 2 312 (45.1) | 33.9 |
| ≥35 | 936 (18.2) | 38.9 |
| Highest education | | |
| No education | 673 (13.1) | 43.3 |
| Primary | 3 385 (66.0) | 37.8 |
| Secondary/higher | 1 071 (20.9) | 28.1 |
| BMI status* | | |
| Normal | 3 400 (66.6) | 38.2 |
| Underweight | 233 (4.6) | 49.1 |
| Overweight/obese | 829 (16.2) | 27.7 |
| Pregnant/postpartum | 645 (12.6) | 34.5 |
| *Maternal (N=5 129)* | | |
| Marital status | | |
| Not married/in-union | 745 (14.5) | 36.3 |
| Married or in-union | 4 384 (85.5) | 36.5 |
| Employment status | | |
| Not working | 1 728 (33.7) | 35.1 |
| Working | 3 401 (66.3) | 37.2 |

...continued

**Table 1. (continued) Percentage distribution and prevalence of under-5 stunting according to child, maternal and household characteristics**

| Characteristics | *n* (%) | Stunted, % |
|---|---|---|
| Number of living children | | |
| 1 | 1 037 (20.2) | 33.6 |
| 2 | 1 258 (24.5) | 37.6 |
| ≥3 | 2 835 (55.3) | 37.1 |
| Health insurance | | |
| Covered | 50 (1.0) | 20.4 |
| Not covered | 5 079 (99.0) | 36.7 |
| Breastfeeding status | | |
| Never | 88 (1.7) | 38.9 |
| Formerly | 3 077 (60.0) | 39.5 |
| Currently | 1 964 (38.2) | 31.8 |
| *Household* (*N* = 5 686) | | |
| Region | | |
| Northern | 631 (11.1) | 35.1 |
| Central | 2 404 (42.3) | 38.2 |
| Southern | 2 651 (46.6) | 36.6 |
| Residence | | |
| Rural | 4 968 (87.4) | 38.9 |
| Urban | 718 (12.6) | 25.0 |
| Wealth status | | |
| Poor | 2 667 (46.9) | 43.1 |
| Middle | 1 101 (19.4) | 36.8 |
| Rich | 1 918 (33.7) | 29.0 |
| Household-head sex | | |
| Male | 4 096 (72.0) | 36.5 |
| Female | 1 590 (28.0) | 38.8 |
| Source of drinking water | | |
| Improved | 4 890 (86.0) | 36.2 |
| Not improved | 796 (14.0) | 42.7 |
| Type of toilet facility | | |
| Improved | 4 600 (80.9) | 36.6 |
| Not improved | 1 086 (19.1) | 39.5 |

*Missing value not reported.



*Fig 1. Percentage distribution of stunted under-5s by age.*

increased till age 12 - 23 months, higher than 37.1% overall prevalence and remained relatively static during the third and fourth years of life, with a slight decline thereafter (Fig. 1).

### Factors influencing stunting among under-5s

The crude and adjusted associations of stunting with child, maternal, household and combined significant characteristics are set out as models 1 - 4 in Table 2. All selected child-related variables, except birth order and recent illness, were significantly associated with stunting. Among the maternal characteristics, only mother's age, education and BMI individually impacted on stunting. Except for household-head sex and toilet type, all household characteristics were significantly associated with stunting.

Model 4 (with the lowest AIC (5 696)) had the best fit. In model 4, the likelihood of being stunted was higher among children aged >23 months (aOR 2.95; CI 2.16 - 4.02), in children who were anaemic (aOR 1.38; CI 1.20 - 1.59), twins or triplets (aOR 2.47; CI 1.66 - 3.68) and had small birth size (aOR 1.61; CI 1.34 - 1.93). It was reduced among females (aOR 0.83; CI 0.73 - 0.94). Stunting was decreased in children of mothers aged 25 - 34 years (aOR 0.76; CI 0.62 - 0.93), who were overweight or obese (aOR 0.78; CI 0.65 - 0.94) and had secondary or higher education (aOR 0.73; CI 0.56 - 0.94). While children from Central Malawi (aOR 1.26; CI 1.03 - 1.55) were more likely to be stunted, those from wealthier households (aOR 0.68; CI 0.58 - 0.81) were less likely to be stunted. The ICC was ≥2% in all the models, suggesting the appropriateness of the choice of our model. A relatively small but significant (ICC 3.0%; *p*<0.05) variation in under-5 stunting was attributed to clustering effect at community level (model 4, Table 2).

### Discussion

We employed GLMM to identify risk factors of stunting among under-5s in Malawi, using nationally representative data. Saliently, the models collectively demonstrate holistic predictors of stunting which include child's age, sex, birth size, birth type, anaemia status, maternal age, education, BMI, the region of residence and household wealth. We found a significant variation in child stunting owing to clustering effect at community level. Notwithstanding many studies on childhood stunting in Malawi, our study was the first to have accounted for the problem of dependency structure and unexplained

residence, wealth quintile, household-head sex, source of drinking water and type of toilet facility on stunting. Lastly, model 4 estimates the combined effects of the significant child, maternal and household characteristics on stunting. In each of the four models, ICC was computed using the estimated random intercept variance.

## Results

### Background characteristics of children under 5

Children and mother's mean (SD) ages were 30.0 (17.1) months and 26.0 (6.7) years, respectively. Household and demographic characteristics categorised by stunting status are described in Table 1. Most children were aged ≥24 months (61.8%) and lived in rural settings (87.4%). Only 1% of respondents were covered by health insurance and one-fifth had attained secondary or higher education. The proportion of stunting decreased with increasing maternal education and BMI.

### Pattern of stunting by child age

Mean (SD) ages of stunted and non-stunted children were 31.7 (15.6) and 29.0 (17.8) months, respectively. The prevalence of stunting
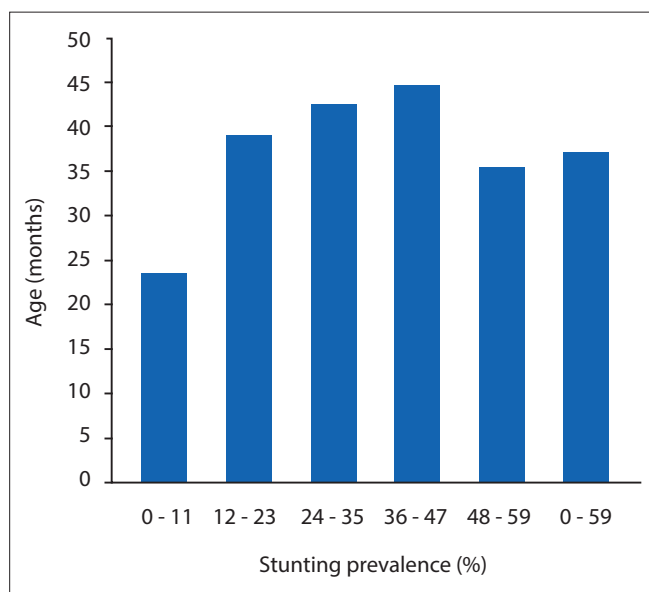
variation in clustered-survey data using GLMM. This is important as child stunting may be inappropriately examined if the nested nature of the dataset like MDHS is ignored.[23]

The observed significant variation between communities is expected as under-5s belonging to the same community of households usually share common unobserved heterogeneity.[22] This suggests that some communities may be at high risk of stunting with others at low risk. The implication is that some determinants of child stunting in this study, which may be propelled by environmental, cultural, behavioural and biological factors, remain unmeasured. This may need further attention as we confirmed the prevalence of under-5 stunting in Malawi to be very high.[2] The prevalence is higher compared with some neighbouring countries such as Zimbabwe (29.2%) and Tanzania (35.5%).[13,24]

Increasing age was significantly associated with stunting. Studies in Malawi[6,8] and other sub-Saharan African countries have also reported similar findings.[11,13,21,25-28] The finding of the lowest prevalence within the first 6 months may likely be linked to the protective influence of breastfeeding, with nearly two-thirds of infants reported to be exclusively breastfed in Malawi.[5] Child's sex was another predictor of stunting in concordance with other studies.[9,20,24,29,30]

**Table 2. Crude and adjusted odds ratios of under-5 stunting in Malawi**

| Background characteristics | Crude model OR (95% CI) | Model 1 aOR (95% CI) | Model 2 aOR (95% CI) | Model 3 aOR (95% CI) | Model 4 aOR (95% CI) |
|---|---|---|---|---|---|
| *Child characteristics* | | | | | |
| Child age, *months* | | | | | |
| <12 | 1 | 1 | | | 1 |
| 12 - 23 | 2.26 (1.86 - 2.75)* | 2.28 (1.77 - 2.93)* | | | 2.27 (1.76- 02.93)* |
| >23 | 2.28 (1.94 - 2.69)* | 2.62 (2.08 - 3.31)* | | | 2.95 (2.16 - 4.02)* |
| Sex | | | | | |
| Male | 1 | 1 | | | 1 |
| Female | 0.85 (0.76 - 0.95)* | 0.81 (0.71 - 0.92)* | | | 0.83 (0.73 - 0.94)* |
| Birth size | | | | | |
| Average | 1 | 1 | | | 1 |
| Small | 1.78 (1.51 - 2.10)* | 1.73 (1.44 - 2.07)* | | | 1.61 (1.34 - 1.93)* |
| Large | 0.92 (0.81 - 1.05) | 0.90 (0.78 - 1.04) | | | 0.89 (0.77 - 1.03) |
| Birth order† | | | | | |
| 1st | 1 | | | | |
| 2nd - 4th | 0.93 (0.80 - 1.07) | | | | |
| >4th | 1.10 (0.93 - 1.30) | | | | |
| Birth type | | | | | |
| Single | 1 | 1 | | | 1 |
| Multiple | 2.92 (2.08 - 4.09)* | 2.37 (1.57 - 3.44)* | | | 2. 47 (1.66 - 3.68)* |
| Birth interval, months | | | | | |
| First birth | 1 | 1 | | | 1 |
| <24 | 1.39 (1.10 - 1.77)* | 1.36 (1.05 - 1.75)* | | | 1.17 (0.85 - 1.61) |
| 24 – 47 | 1.02 (0.87 - 1.18) | 1.00 (0.85 - 1.18) | | | 0.88 (0.67 - 1.15) |
| ≥48 | 0.83 (0.71 - 0.98)* | 0.81 (0.68 - 0.97)* | | | 0.81 (0.60 -1.08) |
| Anaemic | | | | | |
| No | 1 | 1 | | | 1 |
| Yes | 1.33 (1.18 - 1.50)* | 1.48 (1.29 - 1.70)* | | | 1. 38 (1.20 - 1.59)* |
| Recent illness | | | | | |
| No | 1 | 1 | | | |
| Yes | 1.00 (0.89 - 1.13) | 1.04 (0.91 - 1.18) | | | |
| *Maternal characteristics* | | | | | |
| Mother age (y) | | | | | |
| 15 - 24 | 1 | | 1 | | 1 |
| 25 - 34 | 0.81 (0.71 -0.93)* | | 0.71 (0.59 -0.85)* | | 0. 76 (0.62 -0.93)* |
| ≥35 | 0.98 (0.83 -1.16) | | 0.74 (0.59 -0.94)* | | 0. 81 (0.63 -1.05) |
| Highest education | | | | | |
| No education | 1 | | 1 | | 1 |
| Primary | 0.79 (0.66 -0.94)* | | 0.78 (0.65 -0.94)* | | 0.82 (0.67 -1.00) |
| Secondary/higher | 0.52 (0.42 -0.65)* | | 0.56 (0.44 -,0.70)* | | 0.73 (0.56 -0.94)* |
| BMI status | | | | | |
| Normal | 1 | | 1 | | 1 |

...continued

**Table 2. (continued) Crude and adjusted odds ratios of under-5 stunting in Malawi**

| Background characteristics | Crude model OR (95% CI) | Model 1 aOR (95% CI) | Model 2 aOR (95% CI) | Model 3 aOR (95% CI) | Model 4 aOR (95% CI) |
|---|---|---|---|---|---|
| Underweight | 1.30 (0.99 - 1.71) | | 1.32 (1.01 - 1.74)* | | 1.33 (0.99 - 1.77) |
| Overweight/obese | 0.66 (0.56 - 0.78)* | | 0.68 (0.57 - 0.81)* | | 0.78 (0.65 - 0.94)* |
| Pregnant/postpartum | 0.83 (0.69 - 0.99)* | | 0.79 (0.65 - 0.95)* | | 0.87 (0.70 - 1.09) |
| Marital status | | | | | |
| Not married/in-union | 1 | | 1 | | |
| Married or in-union | 1.01 (0.86 - 1.19) | | 1.04 (0.87 - 1.23) | | |
| Employment status | | | | | |
| Not working | 1 | | 1 | | |
| Working | 1.09 (0.96 - 1.23) | | 1.10 (0.96 - 1.25) | | |
| No. of living children | | | | | |
| 1 | 1 | | 1 | | 1 |
| 2 | 1.16 (0.97 - 1.39) | | 1.15 (0.95 - 1.39) | | 1. 27 (0.98 - 1.65) |
| ≥ 3 | 1.15 (0.98 - 1.34) | | 1.26 (1.01 - 1.57)* | | 1. 35 (0.98 - 1.86) |
| Breastfeeding status | | | | | |
| Never | 1 | | 1 | | 1 |
| Formerly | 0.91 (0.57 - 1.45) | | 0.89 (0.56 - 1.42) | | 0. 85 (0.52 - 1.41) |
| Currently | 0.65 (0.41 - 1.04) | | 0.61 (0.38 - 0.98)* | | 0. 97 (0.57 - 1.66) |
| *Household characteristics* | | | | | |
| Region | | | | | |
| Northern | 1 | | | 1 | 1 |
| Central | 1.34 (1.13 - 1.60)* | | | 1.20 (1.01 - 1.43)* | 1.26 (1.03 - 1.55)* |
| Southern | 1.24 (1.05 - 1.47)* | | | 1.13 (0.96 - 1.34) | 1.11 (0.91 - 1.35) |
| Residence | | | | | |
| Rural | 1 | | | 1 | 1 |
| Urban | 0.58 (0.49 - 0.69)* | | | 0.73 (0.61 - 0.88)* | 0.82 (0.66 - 1.01) |
| Wealth status | | | | | |
| Poor | 1 | | | 1 | 1 |
| Middle | 0.79 (0.68 - 0.91)* | | | 0.81 (0.69 - 0.94)* | 0. 87 (0.73 - 1.03) |
| Rich | 0.57 (0.50 - 0.64)* | | | 0.65 (0.56 - 0.75)* | 0.68 (0.58 - 0.81)* |
| Household-head sex | | | | | |
| Male | 1 | | | 1 | |
| Female | 1.05 (0.93 - 1.19) | | | 1.00 (0.88 - 1.13) | |
| Source of drinking water | | | | | |
| Improved | 1 | | | 1 | |
| Not improved | 1.27 (1.08 - 1.50)* | | | 1.12 (0.95 - 1.31) | |
| Type of toilet facility | | | | | |
| Improved | 1 | | | 1 | |
| Not improved | 1.11 (0.96 - 1.28) | | | 0.98 (0.84 - 1.13) | |
| Random effect | | | | | |
| Variance (standard error) | | 0.128* (0.053) | 0.109* (0.045) | 0.067 (0.038) | 0.101* (.051) |
| ICC% | | 3.7 | 3.2 | 2.0 | 3.0 |
| LL | | 2 870.1 | 3 246.7 | 3 646.7 | 2 814.5 |
| AIC | | 5 766.3 | 6 523.3 | 7 313.5 | 5 685.0 |
| *N* | | 4 514 | 5 107 | 5 686 | 4 509 |

ICC = intra-community correlation coefficient; LL = log-likelihood; AIC = Akaike information criteria; *N* = number of observations.
*Significant at 5%.
†Birth order omitted in the adjusted model because of collinearity.
Note: Health insurance excluded from analysis (because nearly all mothers were uncovered).

Female children were less prone to be stunted. This sex disparity may be associated with contextual behavioural patterns of the caregivers, including females' preferential care.[24] However, other studies[13,31,32] found females were more stunted. The racial

disparities across regions and countries might account for this difference.

Infants with respondent-reported small birth size were more stunted. Other literature[9,20,24,27] has corroborated this finding. As

newborn size reflects the intrauterine condition, in addition to preterm birth, small birth size may be partly influenced by maternal nutrition and health status during pregnancy.[31,33] Maternal prenatal healthcare and nutritional well-being, therefore, need attention, especially in preventing low birthweight. The finding that being a twin/triplet heightened the risk of being stunted aligns with other literature.[9,34] This could likely be as a result of maternal food insecurity or inappropriate child feeding practice;[5] for instance, twins tend to struggle to compete for breast milk and other food supplements at the same time, especially in a poor economy setting.[28]

Anaemic children were more prone to be stunted, in tandem with other findings.[12,26,28,35] One study[36] describes a significant relationship between infection, anaemia and stunting. For instance, a study[37] in Malawi has documented that child anaemia could be a product of malaria-in-pregnancy or low birthweight. Relatively few under-5s had malaria-related anaemia according to the MDHS report.[5] Enhancing iron supplementation and antimalarial control in children is a crucial public health intervention.[3,37]

Mother's educational attainment positively impacts on the quality of healthcare a woman receives before, during and after pregnancy or offers her child after delivery.[38] We found a strong association between higher maternal education and lower child stunting. This aligns with earlier findings in the literature.[20,25-27] Addressing stunting requires empowerment of women through education.[20] Evidence of a strong positive association between higher educational attainment and wealth status is replete in the literature.[25-27,32] Lower household wealth status was a significant predictor of stunting in this study, as previously described.[20,25-27] Nearly half of the children resided in poor households, a pointer to inability of the household to procure needed food or medical care.[30] Maternal BMI is indicative of maternal nutritional well-being.[33] The present study suggests that maternal overweight or obesity is linked to decreased child stunting; this has been corroborated by a study in Ethiopia.[39] In contrast, a Kenyan study reported a higher tendency to being stunted with maternal overweight.[25]

Child stunting remains a critical child health problem in the Central region which constitutes 42% of the total population. Risks of stunting were 26% and 14% higher in the Central region compared with under-5s living in northern and southern regions, respectively. These regional variations in stunting can partially be associated with regional differences in geography, race, culture or belief.[18] While one previous study confirms,[30] another found no significant regional differences.[9] The contrasting result may also be attributed to the use of an older MDHS dataset or a statistical method which impedes likelihood-based inference.[23]

## Study limitations and strengths

The present study has some limitations. First, the study design is cross-sectional; the analysed variables can only provide evidence of a statistical relationship but not a causal relationship between the variables and under-5 stunting status. Second, there is a possibility of recall bias as the study included self-reported data without any means of verification. Also, the use of secondary data restricted our potential to sufficiently assess the influence of some characteristics such as dietary intake, feeding practices and national income as drivers of child stunting. Nonetheless, the study has been strengthened by the use of a large nationally representative dataset. Besides, the strength of the work includes carefully adjusting for the potential confounders of stunting, thus taking context into consideration. Also, we uncovered and quantified the extent of hidden characteristics from the effects of the observed characteristics, and this enhanced reliable inferences.

## Conclusions

Our findings emphasise the need to account for hidden characteristics in clustered-survey data. In Malawi, sustained and broadened efforts must be intensified to achieve a 40% reduction in stunting as enshrined in the WHO Global Targets for 2025.[1,31] The relatively small but important observed unexplained variations in stunting across communities should inform intervention strategies that sufficiently address context.

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