

Significant Risk Factors Associated With Stunting for Children Under the Age of 5-years in Malawi: the Application of Proportional Odds Model Using DHS Datasets.

Mzwakhe Magagula (✉ mzwakhemagagula13@gmail.com)

University of KwaZulu-Natal

Shaun Ramroop

University of KwaZulu-Natal

Faustin Habyarimana

University of KwaZulu-Natal

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1 **Title Page**

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3 The Application of proportional odds model using DHS datasets.

4 **Authors:**

5 *Mzwakhe Elmon Magagula, University of KwaZulu-Natal, School of Mathematics, Statistics and
6 Computer Science, Pietermaritzburg Campus.

7 **Shaun Ramroop, University of KwaZulu-Natal, School of Mathematics, Statistics and Computer
8 Science, Pietermaritzburg Campus.

9 ***Faustin Habyarimana, University of KwaZulu-Natal, School of Mathematics, Statistics and Computer
10 Science, Pietermaritzburg Campus.

11 **Corresponding author:** *Mzwakhe Elmon Magagula. Email: mzwakhemagagula13@gmail.com. Cell
12 phone: (+27) 076 479 1804. University of KwaZulu-Natal, School of Mathematics, Statistics and
13 Computer Science, Pietermaritzburg Campus.

14 **Affiliations:** University of KwaZulu-Natal, School of Mathematics, Statistics and Computer Sciences,
15 Pietermaritzburg Campus.

16 **Article Title**

17 **Significant risk factors associated with stunting for children under the age of 5-years in Malawi:**
18 **The Application of proportional odds model using DHS datasets.**

19 **Abstract**

20 **Background**

21 Child malnutrition is perhaps the one of the main medical condition influencing general human wellbeing,
22 mainly in non-industrial nations. The improvement of legitimate evaluations of malnutrition is one of the
23 difficulties encountered by policymakers in numerous countries worldwide. In this manner, the current
24 study was embraced with the essential goal of evaluating and determining all potential determinants of
25 childhood malnutrition in Malawi, using the Demographic and Health Survey (DHS) data 2015/16. The
26 study seeks to reveal some of the significant factors that are perpetuating the incidence of malnutrition in
27 children of Malawi. It also designed to offer deeper insights on how the probability of being diagnosed with
28 this medical condition (malnutrition) evolves across the different levels of the found significant factors.

29 Methods

30 The proportional odds (PO) model was the best model to utilize, motivated by the design of the current
31 study's data set. The PO model is an alternative to conceptualize how the ordinal designed data can be
32 sequentially into dichotomous groups without losing the ordinal nature of response variables. The model is
33 an extension of logistic regression models with two outcomes, it is one of the best models to deal with
34 ordinal response variable comprising of more than two categories. The PO model, as well as the logistic
35 regression models are common classes of generalised linear models (GLMs) mostly used to model
36 association between dependent variable and independent variables.

37 Results

38 The observations derived from fitting the PO model on the Malawi DHS data to investigate risk factors
39 associated with malnutrition (stunting) suggested that: the age of the child; birth type (singleton/multiple
40 births), parents' level of education, household's type of resident; mother's age at the time of birth, mother's
41 BMI, incident of diarrhoea in the last two weeks before the survey, are the most significant independent
42 risk factors of malnutrition (stunting).

43 Conclusions

44 All the aforementioned risk factors are controllable, and they can be improved through intervention
45 strategies. The policies that undergird the country are required to counteract this condition, as the majority
46 of the risk factors need the coherent actions of several governing authorities.

47 Keywords

48 Malnutrition, Stunting, Children under-five, proportional odds model, Malawi

49 **1. Background**

50 Statistically, nearly one in three persons globally suffer from under-nutrition, micronutrient deficiency,
51 overweight, and/or obesity (1). Sub-Saharan Africa has probably the highest level of child malnutrition
52 globally. Hence, a critical look at the distribution of malnutrition within its sub-regions is required to
53 determine the factors that escalate the worst nutritional status in these areas.

54 Determinants of child malnutrition remain an interest of several researchers. In 2017, according to the
55 World Health Organization (WHO) Statistics data visualizations dashboard (2018), the regional average of
56 the prevalence of stunting in the regions of Africa was found to be 33.6% above the global average, which
57 is 22.2%. Furthermore, in 2017, internationally, there were 51 million who were wasted, 151 million kids
58 under five years old who were stunted, and 38 million kids were overweight (2). These numbers support
59 the fact that the prevalence of stunting remains the most problematic form of malnutrition globally.

60

61 Several studies, internationally, have endeavored to disclose elements that influence childhood malnutrition
62 so that relevant measures can be put in place to improve the circumstance straightforwardly (3,4). The
63 WHO has also implemented a United Nations Decade of Action plan on Nutrition. Also, the WHO members
64 have embraced worldwide targets for improving maternal, baby, and little youngster's nourishment and are
65 focused on supervising the progress. These targets are crucial in recognizing need zones for actions and
66 speeding up worldwide change as specified in the global nourishment targets 2025. For example, expanding
67 select breastfeeding in the initial six months of the infants resulted in a 40% to 50% decrease in the quantity
68 of stunted under-five kids (5). These are a few territories, as per WHO, which should be improved to
69 accomplish the target.

70

71 In response to the call of the United Nations Decade of Action on Nutrition, there are positive and unique
72 worldwide execution guides to battle the issue of malnutrition, one of a few such cases in Norway, turning
73 into the primary nation to set up an activity network as a component of the United Nations (UN), the Decade

74 of Action on Nutrition 2016-2025 on 6 June 2017 (1,6) and the Global Action Network on Sustainable
75 Food from the Ocean for Food Security and Nutrition purposes for living for higher need to be given to
76 fisheries and hydroponics in an endeavor to improve worldwide food security (7). Among other activities,
77 part states focused on improving practical food frameworks by creating rational public approaches from
78 creation to utilization across pertinent areas to give all year admittance to food that meets individuals'
79 sustenance needs, advance protected and differentiated sound eating regimens (8).

80 The administrations of Italy, the Russian Federation, Japan, the United Kingdom, and Northern Ireland co-
81 supported an uncommon occasion on reinforcing public obligation to end malnutrition in the entirety of its
82 structures. This occasion was upheld by the Food and Agriculture Organization of the United Nations and
83 the WHO and occurred on 20 September 2016 at the UN Headquarters (9). Many other reports presented
84 by the WHO show how fighting malnutrition is being conducted worldwide, and researchers are also
85 working to identify all the key factors (1).

86 The African region has the largest population accounting for 33.6% of the stunted children globally and a
87 minimum of 20.0% prevalence of wasting in all the regions, according to the WHO's 2018 report (10). As
88 a result, several studies on children's maturational status under five years have been carried out across the
89 regions of Africa, using different methods. These studies' objective was to examine the risk components of
90 children's malnutrition within the African continent. Habyarimana (2017) utilized the proportional odds
91 model to discover malnutrition's main factors, less than five children in Rwanda (11). Another recent study
92 conducted by Taluder (2017) endeavored to reveal the related elements of lack of healthy sustenance among
93 under-five Bangladeshi youngsters by utilizing BDHS information to utilize the PO model (12). Several
94 researchers have already revealed that factors such as mother's and father's level of education, mother's
95 BMI, wealth index, residence's location, antenatal consideration administration during pregnancy, and the
96 interval between successive birth are regular reasons for a poor nourishing status among children under five
97 across the African mainland (11–14).

98 A descriptive and econometric analysis done by Kabubo-Mariara (2008) in Kenya, amplified by policy
99 limitations, was employed to research the effect of the child, parental, family unit, and local area attributes
100 kids' tallness and the likelihood of stunting (15). Critical discoveries from this examination were that male
101 children experience more malnutrition than young ladies, and kids from multiple births are bound to be
102 malnourished than singletons. Various investigations have found that even the age of the kid and youth
103 ailment are critical factors influencing kid dietary status in Africa (13,16)

104 The prevalence of stunting in under-five children is very high in Malawi (37.1% on average), which is
105 above the regional average in Africa (33.6%), according to the joint child malnutrition estimates by the
106 United Nations Children's Fund, the WHO, and the World Bank Group (10). According to the UNICEF
107 global site (2018), in Malawi, 4% of youngsters, particularly those under five years old, experience the ill
108 effects of acute malnutrition, and the more significant part of Malawian kids experience the ill effects of
109 chronic malnutrition, bringing about stunting (17). These numbers are empirical evidence that Malawi is
110 one of the nations with the highest malnutrition occurrence within the Southern and Eastern parts of Africa.
111 Several causes have been attributed to this: food insecurity within public and families, substantial workloads
112 and nourishment of moms, subsequent infections, health-less dietary patterns, and HIV diseases prompting
113 repeated ailment (16). Childhood malnutrition is devastating, and it can be the single most significant
114 contributor to under-five child mortality. In Malawi, unfortunately, there has been only a slight change in
115 children's nutritional status (stunting) since 1992 (48.7%), and stunting rates remain unacceptably high thus
116 far (37.1%), according to the WHO.

117 In Malawi, similar to what other countries are doing worldwide, various stakeholders are attempting to
118 mitigate the impact of malnutrition. Throughout the time frame 2012–2018, UNICEF focused on deterrence
119 of stunting and faltering, the two of which are significant hindrances to children's development and even
120 survival. The initiative was more coordinated towards sound sustenance for pregnant ladies and infants
121 during their initial two years of life. Some strategies to prevent stunting in the country include, but not
122 limited to, supporting the government to develop the Nutrition Act and educating the people living with

123 pregnant women on how to support and encourage the behavioural change for maternal Nutrition and young
124 child and infants nourishing practices (18). All these efforts seem to be promising in ensuring that the
125 average level of stunting is decreasing in the country.

126 In addition to these strategies aimed at preventing the disease, an alternative and effective approach to this
127 endeavor would be to clearly understand the exact factors that escalate the incidence of malnutrition. This
128 study's primary objective is to reveal those factors associated with childhood malnutrition in Malawi using
129 the PO model. An almost similar study by Chirwa (2008) was conducted in Malawi, the researcher used
130 multivariate analysis to investigate factors that determine child malnutrition. The study was conducted
131 using the three anthropometric measures of malnutrition, WAZ for underweight, HAZ for stunting, and
132 WHZ for wasting. Consequently, it was revealed from the Chirwa (2008) study that stunting is the most
133 significant contributor to malnutrition problems amongst the three measures of malnutrition. The current
134 research is fashioned to narrow deep into understanding causes of the most common symptom of
135 malnutrition in Malawi, which stunting, and through the use of the most recent available Demographic
136 Health Survey (DHS) data. We have also taken a deep dive into the specifically addressing the impact of
137 each factors of stunting across different levels. Possible factors are going to be selected, this factors has
138 been used in the different studies conducted across the African continent (4,11,13,16). The study uses
139 association statistics and further uses the regression analysis to analyse information that cannot be revealed
140 by association.

141 **2. Study methodology and Utilised material**

142 **2.1. Data and Definition of variables**

143 Malawi is a landlocked state in south-eastern Africa. Endowed with extensive lakes and spectacular
144 highlands, it is within a narrow, bending piece along with East African Rift Valley land. Lake Nyasa, also
145 recognized as Lake Malawi within Malawi, represents significantly more than one-fifth of Malawi's overall
146 zone. The nation's exports are comprised of production from both minor landholdings and tobacco and tea

147 bequests. The country has achieved an impressive level of worldwide capital in the sort of advancement
148 help that has contributed essentially toward the abuse of its natural assets and has made it feasible for
149 Malawi to, on occasion, produce a food surplus. Notwithstanding, the nation's populace has suffered from
150 persevering malnutrition, especially children under the age of five years, elevated paces of new-born child
151 mortality, and devastating poverty – an oddity regularly connected to an agricultural framework that has
152 supported significant estate proprietors.

153 The data sets used in this study are from the nationwide Malawi DHS 2015 (MWDHS-2015). This data
154 includes an anthropometric component where all children under five listed in the Household Questionnaire
155 were weighed and measured. The study utilized 5092 children, whose complete and plausible
156 anthropometric data were available.

157 **2.2. Dependent variable**

158 This study's dependent variable is the anthropometric measure of height-for-age z-score as an indicator of
159 chronic malnutrition known as stunting. Stunting of children is considered as the best general indicator to
160 gauge the level of wellbeing of children. Moreover, stunting is imperially the highest pervasive form of
161 childhood malnutrition, there is an estimation of around 161 million kids globally, falling under 2 Standard
162 Deviation (SD) from the World Health Association Child Growth Standards middle, height-for-age (19).

163 As a result, in the current study, we considered only the height-for-age anthropometric index to represent a
164 child's nutritional status throughout our investigations. The Z-scores extracted from the height-for-age
165 anthropometric index for each child were calculated to understand the association, if any, between
166 nutritional status and all the selected independent variables. Children's nutrition status (represented by the
167 calculated Z-score) was considered to be a categorical variable with three different ordered levels: severely
168 malnourished (for children with Z-score < -3.0), moderate malnourished (for children with $-3.0 \leq$ Z-score
169 < 2.0), and nourished (for children with Z-score ≥ -2.0). Hence the response variable (nutritional status)
170 was considered an ordinal response variable grouped from a continuous variable.

171 **2.3. Explanatory/independent variables.**

172 The explanatory variables considered are child characteristics and recent child illness, household
173 characteristics, and community characteristics. The child characteristics include the child's age, the gender
174 of the child, birth order, and whether the child is a twin or not. The sex of the child is recorded by a dummy
175 variable equal to 1 for a male and 2 for a female child. If there is gender inequality concerning children's
176 care, we expect female children to be better nourished than male children if female children are favoured
177 and vice-versa. In other studies, female children were found to have a better nutrition status than male
178 children (16). Then we also took into consideration the characteristic of whether a child is from multiple
179 births or not. It was recorded by a dummy variable equal to 1 for a child from multiple births and zero for
180 a single born child.

181 The child's age has an upper boundary of five years, which was measured in months since stunting is the
182 failure to grow optimally and is first detected in children who are considered short for their age group when
183 they are two years old . Therefore, we expect the children who are two years or more to have worse nutrition
184 status than those younger than two years. The child's birth order and recent illness are also characteristics
185 that we are to access against the Nutrition of status of the child. The child's illness was the recent incident
186 of diarrhoea. Whether the child had a fever in the last two weeks or not, both were captured with a dummy
187 variable equal to zero for no incident of diarrhoea or fever. A dummy variable equal to 1 represents a yes;
188 there was recently an incident of diarrhoea or fever.

189 The household characteristics include the household's wealth status, mother's BMI, mother's age at birth of
190 a respective child, mother's working status, mother's highest level of education, father's highest level of
191 education, and father's main occupation grouped. The wealth index of household economic status was
192 constructed in the MWDHS-2015 report by using the information on household ownership of assets and
193 dwelling characteristics. The wealth index was recorded with dummies representing the three categories of
194 poor, middle, and rich. The mother's BMI was captured in two categories, Thin ($BMI \leq 18.5$) and Normal

195 (BMI>18.5). The expectation was that an underweight mother would result in worse nutrition status for the
196 child since she would lack the fat needed to produce adequate milk for her child.

197 The female parent's age at the birth of the respective child was also categorized in five different levels.
198 There is evidence elsewhere that children born to mothers below 18 and above 34 years of age are more
199 likely to be malnourished when compared with the children born to mothers aged 18 to 34 (20).

200 The mother's current working status was captured by a dummy variable equal to one for the currently
201 working mother and 0 for a non-working mother. The highest level of education of a mother was measured
202 with dummies representing four categories: no education, primary, secondary and higher education. The
203 highest level of education for a father was captured in the same manner. Education affects caregiving
204 practices through the ability to process information, acquire skills, and model behaviour. It can be
205 hypothesized; therefore, those educated parents are associated with the child's high nutritional status. They
206 can better use healthcare facilities and ensure a high standard of environmental sanitation (16).

207 Five dummy variables of a father's occupation measure different types of employment. Thus, this
208 independent variable is categorized as not working, professional, business, agriculture, and other
209 occupational sectors. The prevalence of stunting was significantly lowest among the children of fathers
210 who were service holders in a study of predictors of chronic child malnutrition in Bangladesh by Das (2011).
211 One would expect children of fathers who hold professional positions (such as managerial positions) to
212 have better nutritional status since in professional occupations; parents usually get maternity leave to care
213 for their new-born baby, which may help them ensure an early healthy lifestyle for the child.

214 The community variables used in this study include water sources and the type of residence of the
215 household. Source of water is captured with dummy variables for piped water, well water, and other sources
216 (such as rain, tank, etc.). The residence household is captured by dummy variables equal to one for urban
217 and two for rural areas. The expectation is that children from urban areas would be associated with better
218 nutritional status since the availability of health and educational facilities is greater in urban areas compared
219 with rural areas. The duration of breastfeeding was also added to the independent variables to assess the

220 effect of breastfeeding. Breastfeeding is captured by dummies categorized into three groups: ever breastfed,
221 then stopped, never breastfed, and still breastfeeding.

222 Recent several other studies (21–23) utilised the following variables were mostly found to be significant
223 predictors of malnutrition; Socio-economic and demographic characteristics, such as family size, monthly
224 family income, mother can read and write, mother's educational status, mother's marital status feeding
225 practices, diarrhoea in the past two weeks, and age of child variables include. The current study have used
226 some of this variables to investigate association with childhood malnutrition in Malawi.

227 **3. Statistical Analysis**

228 **3.1. Descriptive statistics**

229 The study utilized a quantitative research methodology appropriate for investigating the relationship
230 between two or more variables known as cross-tabulation through version 25.0 of the SPSS statistics
231 application. The use of cross-tabulation enabled us to examine associations within our selected independent
232 variables and the ordered categorical response variable (child nutrition status). Pearson's chi-square test or
233 the Chi-square test of association was used to discover if there is a relationship between the level of stunting
234 and each independent variable. The results of these descriptive statistics are displayed in **Table 1**. The test
235 provided a necessary additional understanding of the data as we were able to isolate the most critical
236 variables (with p-value < 0.005). The chi-square test results show that some of the independent variables
237 are highly significant with the response variables. It is from descriptive statistics results as presented in
238 **Table 1** we were able to select variables to be fitted in the PO model (introduced in section 3.2).

239 Please insert **Table 1** here.

240 **3.2 Model development**

241 Wedderburn and Nelder (1972) led the concept of generalized linear models (GLMs). This type of model
242 expands classical linear models that permit the population to rely upon a linear indicator through a nonlinear

243 link function where the response probability distribution belongs to the exponential distribution family.
244 Wedderburn and Nelder formulated the GLMs with the objective of merging different statistical models,
245 including but not limited to logistic regression, linear regression, and Poisson regression (24). Extensive
246 and deep theory on introduction to GLMs was provided in the book published in 1983 by Nelder and
247 McCullagh. Other different good books can provide excellent references that are giving good examples of
248 the application of GLMs (24–26)

249 3.2.1 Components of generalized linear models

250 A proper kick-off on the discussion of GLMs is to briefly discuss its traditional models from which they
251 emanate, which are known as classical linear models. We consider an observation vector \mathbf{y} possessing n
252 components, which is presumed to be a design of arbitrary variable \mathbf{Y} whose components are distributed
253 independently with μ , the mean of the random variables. The essential technical part of the current model
254 is the classification of the vector μ through the use of a smaller number of unknown parameters β_1, \dots, β_p .
255 For ordinary linear models, we have:

$$256 \quad \mu = \sum_{j=1}^p x_j \beta_j$$

257 Where the β s are unknown parameters and the values of these unknowns are estimated from the empirical
258 data set.

259 Suppose that, for generality, i is observations index, then the essential technical part of the model can be
260 represented by:

$$261 \quad E(Y_i) = \mu_i = \sum_{j=1}^p x_{ij} \beta_j, \quad i = 1, \dots, n$$

262 x_{ij} represent the value of the j th covariate of the observation i . This can be written in matrix form as $\mu =$
263 $\mathbf{X}\boldsymbol{\beta}$ (where \mathbf{X} is $n \times p$, μ is $n \times 1$, and $\boldsymbol{\beta}$ is $p \times 1$), $\boldsymbol{\beta}$ is the parameters' vector, and \mathbf{X} is the matrix of
264 the model. This completes the specification of the systematic part of the model.

265 3.2.2 The generalization

266 The simple path to describe the shift from classical linear models to GLMs is through rearranging the first
267 expression in 3.2.1. The first expression in 3.2.1 is required to have three-part characteristics know as: The
268 systematic component – which is qualified when the covariates x_1, x_2, \dots, x_p produce a linear predictor $\boldsymbol{\eta}$,
269 given by $\sum_{j=1}^p x_j \beta_j$; the random component - which is qualified when the components of \mathbf{Y} are
270 independently normally distributed with the parameters, $\mu = E(\mathbf{X})$ and the constant variance σ^2 ; the link
271 function linking the systematic and random components that is $\mu = \boldsymbol{\eta}$. The latter generalization brings
272 about a new character η which is signifying the linear predictor. The third component of the generalization
273 stipulates that $\boldsymbol{\eta}$ and μ are identical. Suppose that we express $\eta_i = g(\mu_i)$ then $g(\cdot)$ is called the link
274 function. GLMs permit two fundamental extensions, the first being; the distribution of the link function
275 may come from the exponential family other than the Normal. Secondly, the link function may be any
276 monotonic differentiable function. In other words, GLMs can be considered as natural generality of
277 classical-linear-models that permits the mean of the population to entirely rely on linear predictor by means
278 of the (possibly nonlinear) link function. The latter permits the probability distribution of the response to
279 be within the exponential family of distributions.

280 3.2.3 Model Fitting

281 In general, when one is working with data that possesses a categorical response variable, and the categories
282 are more than two, the GLMs provide two choices to be considered by the model developer. The current
283 study utilizes the approach that generalizes the logistic regression through the dichotomous categories of
284 the response into either ordinal or nominal responses. The alternative approach, which is not discussed

285 herein, uses counts or frequencies to model the covariate designs for response variables through Poisson
286 distribution.

287
288 This choice was motivated by the design of the response variable, which is a continuous variable z that
289 measures the severity of disease (malnutrition). Children under the age of five with small values of z are
290 classified as children suffering from "severe malnutrition" or "moderate malnutrition," while children with
291 large or normal values of z are classified as not suffering from malnutrition. The z cut-off points
292 represented by C_1, \dots, C_{j-1} defines j categories with associated probabilities π_1, \dots, π_j , where $\sum \pi_j = 1$.

293
294 Since the possible outcomes for our response variable consist of three categories, and ordinal in design, the
295 use of logistic regression, which is usually model the probability of one of the outcome, named "success"
296 is not applicable. However, there exist regression models that are specifically designed for this situation;
297 these are the expansions of the logistic-regression-model with a response a binary response. The intricacy
298 in fitting ordinal regression models arises to some degree because there are countless opportunities for how
299 "success" and the resulting likelihood of "success" may be represented in the model. Below we discuss one
300 of the commonly used procedures modelling categorical, ordinal response variables.

301 **3.2.4 Proportional odd model (POM)**

302 The investigation that mimics this strategy for dichotomizing the response variable, where the progressive
303 dichotomizations result in cumulative "splits" within the data set, is commonly known as proportional or
304 cumulative odds (27,28). It is one approach to conceptualize how the information may be consecutively
305 divided into dichotomous categories without losing the ordinal nature of those categories (26). The
306 application of this methodology is interesting and easy to execute, because the ordinal feature of the data
307 set similar as dealing with dichotomous data through logistic regression. The PO model's primary objective

308 is to concurrently study the impact of different explanatory variables across the data's conceivable
309 successive cumulative splits.

310

311 The proportional odds model's applications is only valid when the assumption that the dependent variables
312 have the same impact on the odds (29). This assumption is called proportional odds. When this assumption
313 of proportionality is violated, this implies that we have a portion of \mathbf{X} effects with p_1 parameters which
314 fulfils the proportional odds assumption (that is, they have equal slopes), and a portion of \mathbf{Z} effects with p_2
315 parameters which does not fulfil the proportional odds assumption, hence it cannot be fitted by a
316 proportional odds model. The latter situation can be dealt with by other models such as the partial
317 proportional model (PPOM) (13). The functional form of POM has the form described below (13);

$$318 \quad \phi(x) = \ln \left\{ \frac{P(Y = 1|x) + \dots + P(Y = j|x)}{P(Y = j + 1|x) + \dots + P(Y = k|x)} \right\} = \ln \left\{ \frac{\sum_1^j P(Y = j|x)}{\sum_{j+1}^k P(Y = j|x)} \right\}$$

$$319 \quad \phi(x) = \alpha_j + (\beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p), j = 1, 2, \dots, k - 1$$

320 where Y is our response variable, \mathbf{x} is the vector of dependent variables = (x_1, x_2, \dots, x_p) , α_j are intercepts
321 and $(\beta_1, \beta_2, \dots, \beta_p)$ are logit coefficients. The above equation is only valid when the response variable's
322 original design was continuous, then subsequently grouped into categories, and the proportional odds
323 assumption is satisfied. This assumption needs to be tested, and when they are not satisfied, one will have
324 to use alternative models, such as PPOM or others, depending on the design of the response.

325

326 The connection between the proportional-odds cumulative model and the idea of continuous response
327 variable is one of the reasons behind the common usage of this model. Since the response variable (stunting)
328 of the current study is continuous, and categorised into three regions (nourished, moderate and severe) by

329 to cut-points, as defined by the WHO parameters of measuring malnutrition. Hence the regression model
330 of stunting on the chosen explanatory variables take the form:

$$\begin{aligned} 331 \quad \phi(\text{Stunting}) = & \alpha_j + \beta_1 * \text{Child's age} + \beta_2 * \text{Sex of child} + \beta_3 * \text{Birth order} + \beta_4 * \text{Type of birth} + \\ 332 \quad & \beta_5 * \text{Type of residence} + \beta_6 * \text{Mother's education level} + \beta_7 * \text{Father's education level} + \beta_8 * \\ 333 \quad & \text{Household wealth index} + \beta_9 * \text{Mother's BMI} + \beta_{10} * \text{Mother's age at birth} + \beta_{11} * \\ 334 \quad & \text{Mother's working status} + \beta_{12} * \text{Mother's age at birth} + \beta_{13} * \text{Source of water} + \beta_{14} * \\ 335 \quad & \text{Duration of breastfeeding} + \beta_{15} * \text{Had diarrhea recently} + \beta_{16} * \text{Had fever in last two weeks}, j = \\ 336 \quad & 1, \dots, 16, \end{aligned}$$

337 **4. Results and discussion**

338 **4.1. Model assumptions testing**

339 The study has an ordinal response variable which is nutritional status. As discussed above, the ordinal
340 response variable was derived by grouping a continuous variable; the height-for-age anthropometric index.
341 Statistically, when one has such a data design, it is appropriate to formulate a PO model. The chi-square
342 score has then utilized to test the appropriateness of developing the PO model; testing the PO assumption.
343 This test is primarily conducted to confirm whether the main PO model assumptions are violated or not.
344 However, there are empirical concerns about the chi-square score test; it tends to result in a too-small p-
345 value. As a result, the current study conducted, above the chi-square score test, a supporting technique for
346 investigating the PO assumption. This technique computes the single score tests for each covariate as an
347 alternative method of testing whether the PO assumption is violated (30). Results of the test are displayed
348 in **Table 2**.

349 Firstly, from **Table 2**, the chi-square score test for testing the PO assumption is not significant at a 5% level
350 of significance ($\chi^2 = 36.94$, p-value = 0.3347). Therefore, the design of our data set does not violate the PO
351 assumption. In addition, this demonstrates that for every one of the picked covariates, one parameter may
352 be utilized for separate modelling logits of cumulative probabilities. However, to confirm the chi-square

353 test results' correctness, we have conducted the alternative or supporting testing technique; single covariate
354 score test. The outcome of the letter test is displayed in the last column of **Table 2**. The outcome indicates
355 that all the covariates were insignificant ($p\text{-value} \leq 0.005$), and hence, they satisfy the PO assumption. From
356 the latter results, we were able to make a final decision that our dataset satisfies the PO assumption for
357 POM.

358 **4.2. Discussions**

359 The observations from fitting the PO model for determining risk factors for childhood stunting in Malawi
360 are displayed in **Table 2**. We have evaluated the goodness-fit test to assess the PO model's overall adequacy
361 on the data set. The test results suggested that the overall model did not lack any type of fit, with $p\text{-value} =$
362 $<.0001$ (see the last row of **Table 2**). The data set used in the current study was collected in 2015/16 DHS.
363 Hence, the study results must be read as a likelihood that similar conditions are still evident in Malawi. This
364 is a strong assumption motivated by the argument of no evidence, which suggests that the risk factors of
365 stunting revealed by the current study have already been addressed.

366 The column labelled odds ratio in **Table 2** displays the values of the estimated adjusted odds ratios.
367 Therefore, the interpretation of our results is based on adjusted odds ratios. The PO model results revealed
368 that the odds of possessing worse nutrition status (stunting) are 3.62, 4.19, and 3.91 higher among children
369 belonging to the age group 12-23, 36-47, and 48+ months respectively when compared with the infants.
370 This result supports the earlier hypothesis; stunting can be clearly identified when the child is two years
371 old. Moreover, this result supports evidence from a study on childhood malnutrition conducted by Das
372 (2008) in Bangladesh. It can be surmised that when a child is growing, the mother's milk alone becomes
373 insufficient for feeding. As a result, we can confidently state that the reason for increased odds of stunting
374 in children of 12 or months is attributed to inadequate supplementary foods when breastfeeding is no longer
375 adequate. The odds of stunting in children younger than five years can worsen as age increases; however,
376 this is evident up to a certain age (47 months), beyond which then the odds of stunting improve materially.

377 The results of the PO model displayed in **Table 2** also suggest that kids from multiple births have 3.66 (odds)
378 times higher odds of possessing stunting compared to children of single births (with p-value = <.0001). The
379 observation could be attributed to the low birth weight for children from multiple births, insufficient food
380 intake from breastfeeding, and competition for nutritional intake, which will distress the offspring of
381 multiple births. Furthermore, we can attribute this to the fact that, in general, parents can care more for
382 fewer kids, which can be added as a justification for the high risk of stunting in multiple birth children. As
383 an individual, I also applaud the Human Fertilization and Embryology Authority in its efforts to reduce
384 multiple births through the “one at a time” campaign (31); African nations can also follow other countries
385 in imposing a single embryo transfer policy – this alone may play a significant role in decreasing the risk
386 of childhood medical complications caused by multiple births, possibly even the prevalence of stunting.

387 The results from **Table 2** also reveal that the difference in a mother's education level plays a significant role
388 in the risk of poor nutritional status of a child. The children of illiterate mothers (with no education) have a
389 high likelihood of having a poor nutritional status (about 2.0 times) when compared with mothers with
390 higher educational qualifications. Compared with children of fathers with higher education levels, the risk
391 of stunting was found to double (2.144) for children of fathers with only primary school as their highest
392 level of education. These results highlight the importance of education as an essential determinant of child
393 malnutrition in Malawi. This finding is common, and many studies have attempted to explain this difference
394 in malnutrition in relation to parents' education levels (e.g., (13,16)). There is a common belief that educated
395 mothers may be more conscious about the health of their children. As a result of their educated status, they
396 can easily research, identify and adopt new feeding practices, which may help to significantly improve the
397 nutritional status of their children.

398 Household factors make a substantial contribution to the nutritional status of under-five children. Usually,
399 children in households with the lowest income have the worst nutritional status, and this improves with the
400 increased wealth status of the household (13). In the current study, the results indicate that children from
401 households with a poor wealth index status are 1.55 times more at risk of a poor nutrition status as compared

402 with children from households classified under the rich wealth index status (**Table 2**). However, there was
403 no significant difference in the likelihood of a poor nutrition status between children from households with
404 either moderate or rich wealth index status. The results support the statement; "growth of infants and
405 younger children throughout the world is related to the socio-economic environment in which they live"
406 (14).

407 Another interesting observation from the results from the PO model is that odds of the stunting condition
408 are observed to be significantly different between children of mothers with normal ($BMI \geq 18.5$) and thin
409 ($BMI < 18.5$) body mass index (BMI). Children of mothers with a BMI indicating underweight ($BMI <$
410 18.5), compared with those with a normal body mass index, are about 1.5 times more likely to be severely
411 stunted. There are prolific number of research studies available also showing the association of BMI and
412 malnutrition (13,32–34). Furthermore, the model reveals that the odds of having malnutrition (stunting),
413 for the under-five children in Malawi, are lower for children born to mothers over 18 years of age at birth
414 when compared with mothers who gave birth when under 18. **Table 2** reveal that children born to mothers
415 aged 19-23, 24-29, and 30-34 were 0.89, 0.577, and 0.57 less likely to have chronic malnutrition (stunting)
416 when compared with children of mothers who gave birth when they were below the age of 18 years. The
417 results support the inherent results that generally, children born to mothers below 18 and above 34 are more
418 susceptible to malnourishment than children born to mothers aged within 18-34 years (20,35).

419 Within the two weeks before the survey, children who suffered from diarrhoea were at a 1.2 times higher
420 risk of being malnourished than children who did not suffer from diarrhoea during the same time period
421 (**Table 2**). This suggests that the illness history of the child can serve as one of the determinants of
422 malnutrition. Number of studies have also postulated the reciprocal relationship between malnutrition and
423 diarrhoea (36,37).

424 Inset **Table 2** here.

425 **Conclusions**

426 The current research was conducted with the primary goal of revealing factors that might be associated with
427 the condition of high childhood malnutrition in Malawi. The study revealed the risk factor of malnutrition
428 in Malawi and deeper insights on how the probability of stunting evolves across the different levels of risk
429 factors. The risk factors of malnutrition from the current study are found to be; the age of the child; birth
430 type (singleton/multiple births), parents' level of education, household's type of resident; mother's age at
431 the time of birth, mother's BMI, the incident of diarrhoea in the last two weeks before the survey. From the
432 results of the current study, we can deduce that Malawi's economic state is possibly the centre of the causal.
433 However, this can be subjective as it was not proven by any statistical model utilized herein. All the risks
434 mentioned above factors are controllable, and they can be improved one way or another. In US Government
435 launched the Feed the Future Guide, describing its strategy to address global hunger and food security. The
436 strategy emphasizes that investments in addressing the root causes of under-nutrition can improve the lives
437 of mothers and their children. Likewise in Malawi, collective government's interventions are required to
438 counteract this condition

439 **List of Abbreviations**

440 All acronyms were qualified on the text.

441 **Declarations**

442 See below

443 **Ethics approval and consent to participate**

444 Before each interview is conducted, an informed consent statement is read to the respondent, who may
445 accept or decline to participate. A parent or guardian must provide consent prior to participation by a child
446 or adolescent. Participation was voluntary, and all individuals provided verbal informed consent according
447 to approved survey protocols. This article features a secondary analysis of publicly available DHS data
448 which does not require further ethics approval.

449 Procedures and questionnaires for standard DHS surveys have been reviewed and approved by Informed
450 Consent Form (ICF) Institutional Review Board (IRB). Additionally, country-specific DHS survey
451 protocols are reviewed by the ICF IRB and typically by an IRB in the host country. ICF IRB ensures that
452 the survey complies with the U.S. Department of Health and Human Services regulations for the protection
453 of human subjects (45 CFR 46), while the host country IRB ensures that the survey complies with laws and
454 norms of the nation. In Malawi, the survey protocol, including biomarker collection and testing procedures
455 were reviewed and approved by the National Health Sciences Research Committee in Malawi and the ICF
456 Institutional Review Board.

457 Details on ethical procedures are provided in the annexes to DHS reports and on the DHS
458 website: <https://dhsprogram.com/What-We-Do/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm>.

459 **Consent for publication**

460 Not Applicable

461 **Availability of data and materials**

462 The dataset used in the current study can be obtained from the DHS website upon request. Please register and
463 request the Malawi DHS 2015-16 data
464 at: http://www.dhsprogram.com/data/dataset_admin/login_main.cfm. The data must not be passed on to
465 others. All DHS data should be treated as confidential, and no effort should be made to identify any
466 household or individual respondent interviewed in the survey

467 **Competing interests**

468 The authors declare that they have no competing interests

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471 **Authors' Information**

472 **Affiliations:**

473 University of KwaZulu-Natal, School of Mathematics, Statistics and Computer Sciences,
474 Pietermaritzburg Campus.

475 **Authors' names**

476 Mzwakhe Elmon Magagula (Author-1), Statistics PhD Student; Shaun Ramroop (Author-2), Full
477 Professor of Statistics at UKZN & Faustin Habyarimana (Author-3), Senior Lecturer of Statistics at
478 UKZN.

479 University of KwaZulu-Natal, School of Mathematics, Statistics, and Computer Sciences,
480 Pietermaritzburg Campus.

481 **Authors' Contributions:**

482 MME: is the primary author, responsible for implementation and application of all the conceptualisations
483 of the study.

484 SR: 'contributed' in the design and conceptualisation of the study. He is my supervisor, he does all the
485 reviews and validation of the findings. He validated the statistical parameters and model appropriateness
486 for the current study.

487 FH: 'contributed' in the design and conceptualisation of the study as well. He is my co-supervisor, his
488 technical contributions to the writing and coding has made it possible for us to come up with robust findings.
489 He validated all the findings and the interpretations thereof.

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572

573 Tables

574

575 **Table 1: Children's nutritional status according to selected independent variables**

Level of Stunting (Height-for-Age)					
Covariates	Severe	Moderate	No stunting	Total	Chi-square χ^2 (p-value)
	(z-score < -3.00)	(-3.00 ≤ z < -2.00)	(z-score ≥ -2.00)		
Independent Variables of Stunting (%)					
Child's age (in months)					
6	11 (1.9)	43 (7.5)	518 (90.6)	572	175.8(0.000)
7-11	14 (3.2)	63 (14.4)	359 (82.3)	436	
12-23	81 (7.7)	280 (26.6)	690 (65.7)	1051	
24-35	70 (6.9)	219(21.5)	729 (71.6)	1018	
36-47	114 (10.8)	243 (23.0)	701 (66.3)	1058	
48-59	78 (8.2)	217 (22.7)	662 (69.2)	957	
Sex					
Male	190 (7.6)	526 (21.0)	1784 (71.4)	2500	1.15(0.562)
Female	178 (6.9)	539 (20.8)	1875 (72.3)	2592	
Birth order					
1	87 (6.9)	279 (22.0)	901 (71.1)	1267	7.5(0.279)
2-3	134 (6.8)	394 (20.0)	1439 (73.2)	1967	
2-3	83 (7.2)	235 (20.5)	831 (72.3)	1149	
6 ⁺	64 (9.0)	157 (22.1)	488 (68.8)	709	
Residence					
Rural	327 (7.7)	947 (22.2)	2996 (70.2)	4270	37.5(0.000)
Urban	41 (5.0)	118 (14.4)	663 (80.7)	822	
Mother's education level					
No education	73 (11.6)	150 (23.8)	408 (64.7)	631	62.7(0.000)
Primary	246 (7.4)	725 (21.8)	2355 (70.8)	3326	
Secondary	49 (4.6)	183 (17.3)	823 (78.0)	1055	
Higher	0 (0.0)	7 (8.8)	73 (91.3)	80	
Father's education level					
No education	30 (7.6)	95 (23.9)	272 (68.5)	397	

Primary	199 (8.4)	516 (21.7)	1658 (69.9)	2373	50.0(0.000)
Secondary	69 (5.2)	252 (19.2)	994 (75.6)	1315	
Higher	5 (2.6)	15 (7.9)	171 (89.5)	191	
Wealth status					
Poor	214 (9.5)	552 (24.6)	1480 (65.9)	2246	93.9(0.000)
Middle	61 (6.1)	223 (22.2)	721 (71.7)	1005	
Rich	93 (5.1)	290 (15.8)	1458 (79.2)	1841	
Mother's BMI					
Thin (BMI < 18:5)	24 (9.3)	66 (25.6)	168 (65.1)	258	6.1(0.047)
Normal (BMI 18:5)	342 (7.1)	998 (20.7)	3477 (72.2)	4817	
Mother's age at birth of the respective child (years)					
18	17 (8.8)	36 (18.7)	140 (72.5)	193	19.4(0.013)
19-23	109 (8.0)	319 (23.3)	941 (68.7)	1369	
24-29	96 (6.0)	315 (19.8)	1177 (74.1)	1588	
30-34	64 (6.5)	190 (19.2)	738 (74.4)	992	
35+	82 (8.6)	205 (21.6)	663 (69.8)	950	
Mother's working status					
Currently working	248 (7.4)	727 (21.6)	2393 (71.1)	3368	3.3(0.193)
Not working	120 (7.0)	338 (19.6)	1266 (73.4)	1724	
Father's occupation					
Not working	31 (8.6)	72 (19.9)	258 (71.5)	361	25.0(0.002)
Professional	17 (5.0)	52 (15.4)	269 (79.6)	338	
Business	18 (6.4)	47 (16.7)	216 (76.9)	281	
Agriculture	127 (7.5)	399 (23.6)	1168 (68.9)	1694	
Other+	113 (6.9)	316 (19.4)	1199 (73.6)	1628	
Birth type					
Singleton	342 (6.9)	1015 (20.6)	3578 (72.5)	4935	38.0(0.000)
Multiple birth	26 (16.6)	50 (31.8)	81 (51.6)	157	
Duration of breastfeeding					
Ever, then stopped	262 (8.5)	691 (22.4)	2127 (69.1)	3080	36.0(0.000)
Never breastfed	4 (4.9)	19 (23.5)	58 (71.6)	81	
Still breastfeeding	102 (5.3)	355 (18.4)	1474 (76.3)	1931	
Source of water					
Piped water	48 (4.3)	175 (15.8)	887 (79.9)	1110	
Well water	284 (7.8)	821 (22.4)	2558 (69.8)	3663	

Rainwater, tank, other	36 (11.3)	69 (21.6)	214 (67.1)	319	52.8(0.000)
Had diarrhea in the last two weeks					
No	258 (7.3)	730 (20.6)	2558 (72.1)	3546	0.8(0.663)
Yes	109 (7.1)	334 (21.7)	1096 (71.2)	1539	
Had a fever in the last two weeks					
No	289 (7.2)	823 (20.5)	2903 (72.3)	4015	1.8(0.402)
Yes	77 (7.3)	236 (22.3)	743 (70.4)	1056	

576

577 **Table 2: Results of the fitted PO Model**

Covariates	Regression Coefficient	Standard Error	p-value	Odds Ratios	Single Score test (p-value)
Intercept1	-2.1226	0.2037	<.0001	-	-
Intercept2	-0.4293	0.1993	0.0313	-	-
Child's age (in months) [0-11 months as a reference]					
12-23	0.2632	0.0894	0.0032	3.620	0.056
24-35	0.0074	0.0776	0.9236	2.803	
36-47	0.4106	0.0818	<.0001	4.195	
48-59	0.3420	0.0877	<.0001	3.917	
Sex of child [Male as a reference]					
Female	-0.0241	0.0351	0.4932	0.953	0.382
Birth order [First as a reference]					
2-3	-0.0227	0.0685	0.7397	1.087	0.673
3-6	0.0248	0.0758	0.7433	1.140	
6+	0.1043	0.1089	0.3381	1.235	
Type of birth [Singleton as a reference]					
Multiple	0.6485	0.0901	<.0001	3.658	0.718
Type of residence [Rural as a reference]					
Urban	-0.0143	0.0656	0.8279	0.972	0.446
Mother's education level [higher as a reference]					
No education	0.3083	0.1437	0.0319	1.735	0.130
Primary	-0.0188	0.1247	0.8804	1.251	
Secondary	-0.0471	0.1298	0.7168	1.216	

Father's education level [higher as a reference]					
No education	0.1389	0.1197	0.2458	1.921	0.358
Primary	0.2488	0.0879	0.0047	2.144	
Secondary	0.1263	0.0896	0.1585	1.897	
Household wealth index [Rich as a reference]					
Poor	0.2279	0.0516	<.0001	1.551	0.274
Middle	-0.0173	0.0591	0.7698	1.213	
Mother's BMI [Normal as a reference]					
Thinness (BMI < 18.5)	0.1867	0.0775	0.0160	1.453	0.862
Mother's age at birth [18 years as a reference]					
19-23	0.2347	0.0895	0.0087	0.894	0.565
24-29	-0.2028	0.0820	0.0134	0.577	
30-34	-0.2150	0.0991	0.0301	0.570	
35+	-0.1638	0.1211	0.1762	0.600	
Mother's working status [Not working as a reference]					
Currently working	0.0343	0.0407	0.3992	1.071	0.575
Father's type of occupation [Professional as a reference]					
Not working	-0.0136	0.1135	0.9049	0.921	0.530
Business	-0.0855	0.1259	0.4972	0.857	
Agriculture	0.0401	0.0711	0.5731	0.972	
Other	-0.0093	0.0679	0.8910	0.925	
Source of water [Piped water as a reference]					
Well water	-0.0002	0.0620	0.9975	1.141	0.161
Other, rainwater, tank, etc.	0.1327	0.0970	0.1711	1.304	
Duration of breastfeeding [Still breastfeeding as a reference]					
Ever, then stopped	0.0581	0.1081	0.5908	0.966	0.291
Never breastfed	-0.1510	0.1916	0.4306	0.784	
Had diarrhea recently [No as a reference]					
Yes	0.0898	0.0453	0.0472	1.197	0.503
Had fever in last two weeks [No as a reference]					
Yes	0.0105	0.0392	0.7883	1.021	0.489

Score test for the Proportional Odds Assumption: Chi-Square (χ^2) = 36.94, df = 34, p-value = 0.3347

Goodness-of-fit of overall model (Likelihood Ratio): Chi-Square (χ^2) = 330.60, df = 34, p-value = <.0001