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Children Early Nutrition Supplementation and Augmenting Factors in Teaching of Reading in Lungwena, Mangochi District, Malawi

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Abstract
The study investigated the effect of early nutrition supplementation on children's reading ability and factors that augment reading skills in children at pupil, household and school level. The study followed up on children that were provided with early nutrition supplementation in varying levels of intensity with a standardised reading test that was levelled for children with an equivalent of two years of primary education to determine how the nutrition supplementation affected their ability to read. The study used a multi-level random effects regression to determine effects that were due to children exposure to school, household and individual factors. The variables that were key at each level of effect were determined through a Principal Component analysis, and later regressed to determine those variables that were key to their reading abilities. The study did not find statistical significance on household and school effects but child specific variables. The study found that intensity of nutrition that a pupil takes in early years affect their ability to acquire reading skills. This was augmented by the number of times a pupil practice reading and availability of textbooks to read, including well stocked and utilized libraries available in schools where pupils were enrolled.

Keywords: Nutrition, Supplementation, Teaching and Reading, Malawi

1. Introduction

Better nutrition for children in early years has a positive effect on their cognitive abilities (Glewwe, P., Jacob, H.G. and King, G.E., 2001). Good nutrition status positively relates to child growth, however, the notion of better nutrition preventing children stunting is challenged by other theorists who attributes 60% of children growth for height to genetic make-up and the rest of 40% to nutrition (Lai, 2006). Therefore, despite the variances or lack of thereof, early nutrition will affect cognitive performance of children in their early education as shown in studies that have situated vertical body growth as key to high academic and professional performance (Berkman, D.S., Lescano, A.G., Gilman, R.H., Lopez, S.L., and Black, M.M., 2002). These findings leave an inconclusive linkage between nutrition and cognitive performance, nutrition and stunting, and academic performance based on age for height. It is unclear whether nutrition is the common denominator or whether genes take precedence nor whether height affects how children perform academically.

Unrelated to the theorists and studies mentioned above, a group of researchers conducted a longitudinal study in Malawi's lakeside district of Mangochi. The study monitored growth patterns in 840 children. The children enrolled in the study were selected from birth. After the selection, the children were randomly assigned to groups where they were provided with nutrition supplements in varying quantities and types to monitor the effect of the supplements on the children growth patterns. The children were supported for 36 months. Parents/ Guardians of the participating children received nutrition education to sustain nutrition practices in their homesteads during the programme period as well as after the children's graduation from the programme based on the application of adult teaching theories on nutrition adapted from Piaget's theory on learning, that state that learning influences behaviour(Hatice BA ., K., Zuhal, B. Günsel, B.A. Meziyet, 2009), hence the assumption that providing nutrition education to parents of the selected children will lead to parents continued behaviour in supporting the nutrition of the children post-intervention implementation.

The children under the intervention above, were randomly selected into four arms of treatment: 1) standard treatment i.e. no extra food supplements (but dietary supplementation between 18 and 30 months of age), 2), "standard" fortified spread with milk-powder as the protein source 3) modified fortified spread with soy-powder as the protein source, and 4) fortified maize-soy flour (likuni phala, LP) for monitoring effect of nutrition supplements on their growth. Results from the study did not show significant variation in height amongst nutrition groups. However, the group with higher uptake of nutrition intensity had children doing statistically, marginally well on height for age than others (Phuka, John,.et.al, 2009). The findings showed that there was an effect on the variation of nutrition intake on growth trends of the participating children though not significant in overall terms. There was no direct explanation on the absence of observed significant effect regardless of the nutrition supplements. However, based on other studies conducted on nutrition and child vertical growth, gene-effect could be a speculative reason behind the results (Lai, 2006). Nonetheless, the gene-effect is contested where regardless of genes of first-generation parents, there is a remarkable growth patterns e.g. the case of children born to Chinese parents, where malnutrition is linked to location, and there is a clear positive correlation on nutrition and urbanisation (Jamison, 1986) . This suggests that malnutrition is largely an economic induced condition from failure to procure nutritious food and/ or lack of knowledge on eating practices and regimes that promote better nutrition uptake. Therefore, regardless of genes, everyone has potential for better growth that is also associated with better academic performance or cognitive abilities.

Based on various research and studies that have linked pathways on maternal knowledge on health nutrition practices to lesser incidences of malnutrition and therefore better cognitive development and academic performance (Frost, M.B., Forste, R., and Haas, D.W., 2005; Glewwe, P., and Miguel, E.A., 2007) , height to better academic performance (Spears, 2012), this study has followed-up children who benefited from the intervention above with a reading test and measurement of their height post-intervention. This was done to test the findings of others who have concluded on a positive pathway on nutrition, better height and better academic ability. Therefore, the study has used the four levels of nutrition supplementation intensity mentioned above and assessed how students in those groups performed in their acquisition of reading skills. Noteworthy mentioning that all children who participated in the nutrition interventions and proceeded to enroll in primary schools went through a standardised phonics literacy curriculum. All participating schools were similarly resourced in terms of trained teachers, teaching instruction materials, textbooks and received similar coaching and mentoring instructional support. Therefore, the assumed expectation was that children enrolled in these schools should perform within similar range, otherwise, variation in children's performance to acquire reading skills will have to be explained by other factors such as nutrition and other augmenting factors included in this study.

The treatment arms referred above, were provided by the Malawi College of Medicine in collaboration with Finland's Tempere University. A reading test standardized for pupils with equivalent two years of education was adapted from the Malawi Government's National reading programme to test the children who were traceable on their ability to read. The test items included letter identification, letter naming, syllable reading, oral reading fluency and comprehension, administered in Chichewa, a local language commonly used in schools where the traced pupils were enrolled. The 301 students that were traced had an average of 11 years, implying that they were traced close to 8 years after the early nutrition supplementation. Further to the administration of the reading test, the study collected data at pupil, school and household level to understand the homogeneity or lack thereof of other factors aside the early nutrition received. This was done to examine the effect (if any) that early nutrition supplementation had on reading skills of the pupils and whether there are any augmenting factors that affecting the way a child learns top read, hence variation in their reading scores.

2. Experimental/Materials and methods

The study listed all children who were enrolled in the Lungwena Child Nutrition Study by treatment arm as implemented by the Malawi's Kamuzu University of Health Sciences and Tempere University of Finland in Malawi, Mangochi District, Lungwena. Thereafter a team of researchers went out tracing availability of the children in the study area, those available were re-listed and traced further back to the nutrition supplementation treatment arm that they belonged. An early grade reading test comprising of five key test-items (letter naming, letter identification, syllable reading, oral reading fluency and comprehension) was adopted from the Malawi National reading Programme for use in testing their reading abilities. After administration, the test was marked, scores of the test were entered in SPPS package for each pupil per school and uniquely identified by their identification numbers in the original random listing on the nutrition intervention. Further inquiry was conducted on household factors that have proven to contribute to the ability of pupils to learn reading and were taken as augmenting factors such as 1) times a pupil is read to at home (Roundy, A.R. and Roundy, T.P., 2009; Pang, E.S., Muaka, A., Bernhardt, E.B., and Kamil, M.L., 2010; Mastropieli, M.A., Leinart, A., and Scruggs, T.E., 1999; Denton, C.A., Anthony, J.L., Parker,R., and Hasbrouck, J., 2004), 2) language used at home (Harrington, M., & Sawyer, M., 1992; Dickinson, D.K., & McCabe, A., 2002), 3) Meals taken per day (Howard, 2010) and (Wesnes, K.A., Pincock, C., & Scholey, A., 2012); and school attendance (Roby, 2004), and (NCES, 2009; Aden, A.A., Yahye, Z.A., & Dahir, A., 2013) . Further data was collected at each school where the pupils were enrolled. This was conducted to trace school resource factors that directly contribute to ability of pupils to learn to read such as 1) availability of girl latrines, 2) Teacher latrines, 3) Teaching staff room, 3) Class spaces, 4) Well-groomed grounds, 5) Electricity, 6) Clean water availability, 7) Textbooks availability, 8) Teaching guides' availability, 9) Well stocked library, 10) Teacher mentoring and coaching and 11) Availability of desks as researched by others including (Godhaber, D.D., & Dominic, B,J., 1990), (Llomo, O., & Mlavi, B., 2016) and (Hanushek, 1997). Further data at pupil level was collected on factors such as age, height of children, head circumference and gender to find out if there is evidence that support their contribution to learning of reading by pupils.

The data was collected at all these levels to enable the study show key factors at school, household and pupil level that augments the ability of children to learn reading skills in addition to the effect of early nutrition on learning ability (Frost, M.B., Forste, R., and Haas, D.W., 2005; Glewwe, P., and Miguel, E.A., 2007) .

The observation obtained from the respondents were entered in SPSS and analyzed in STATA to describe the data, conduct a Principal Component Analysis (PCA) for factor analysis on key predictors of reading ability at school and household level and further statistical modelling through multi-level mixed methods regression analysis to linear mixed model regressions and analysis of variance to detect key predictors that affected ability of pupils to learn reading.

2.1. Model specification

The study examined the possible effects of increased intensity of nutritional supplementation interventions on early acquisition of reading skills. The data therefore consist of pupils (level 1) nested in households (level 2) and nested within schools (level 3). Due to the three-level nature of the data structure, measuring these effects necessitates fitting three-level multilevel linear models to examine the relative importance of schools and households as influences on reading ability of pupils. In the nutritional supplementation programme, random assignment of children to the four interventional conditions: A) delayed supplementation; B) standard supplementation; C) modified supplementation; and D) Likuni phala, were done at household level. It may therefore seem more likely that some parents or guardians would have been more enthused to sustain the feeding practices, consequently having a direct effect on growth of the pupils', subsequently, influencing their reading abilities.

In addition, the study expected that pupils who received the same intervention would cluster in the same household, and pupils from different households who received the same intervention would cluster in the same school. Consequently, there would likely be variation among different schools in terms of reading practice at school level, availability of resources and environment for learning, as well as variation among households in terms of, reading practice, language, and meals taken per day, and availability of resources, at household level. Therefore, these would likely have an indirect effect on the reading ability of the pupils. Variation in pupils' reading abilities is therefore expected in both between-school and within-school-between-household variation in pupils' reading ability.

2.2. Model Assumptions

The model assumed that: 1) A linear relationship existed between the response variable and each predictor, 2) Predictors were not highly correlated, 3) Variances of sub-samples were equal, 4) Residuals were normally distributed and 5) Observations at each level were clustered, and therefore not independent.

2.3. Exploratory data analysis

The study response variable(s) such as ability to name letters (letter sounds), ability to know the letters (alphabet), reading fluency (number of words a pupil is able to read per minute), ability of a pupil to listen to a story and answer questions from the story (listening comprehension) and ability of pupils to read a story on their own and answer questions from the story (reading comprehension) were numericised and scores computed on a 101-percentage points (0% - 100% in order to calculate mean scores.

2.4. Normality of residuals of the mean score of reading ability

The study used a normal p-p plot of the residuals of the mean score of reading ability for each pupil to assess the behaviour of the residuals and ensure that data used in the analysis of the study was normalized. Where data showed non-normality, mean scores were centered through standadisation and computation of z-scores.

2.5. Building the Level-1 Model

The study model was specified as below:

$$z\_mscore_{ijk} = \beta_0 + v_k + u_{jk} + e_{ijk} \text{ (Random intercept model) ... (1)}$$

$$z\_mscore_{ijk} = \beta_0 + \beta_1 X_{ijk} + v_k + u_{jk} + e_{ijk} \text{ (Model with pupil level predictors) … (2)}$$

Where X_{ijk} is a vector of pupil level predictors; β_0 is the mean of *z_mscores* across all schools; β_1 is a vector of individual level effects; and

$v_k \sim N(0, \sigma_v{}^2)$ is the school level effect

$u_{jk} \sim N(0, \sigma_u{}^2)$ is the household level effect

$e_{ijk} \sim N(0, \sigma_e{}^2)$ is the residual error

The study also assessed the coverage intervals of the data to check the absolute magnitude of variance components. Furthermore, the study assessed the Variance Partition Coefficients to check the level of attribution of the data that was used in the study. Thereafter an Intra-class correlation coefficient was calculated to check the similarities of the implied coefficients within schools and within households, and thereafter the study conducted a random variable test to predict the school and household random effects. Furthermore, the study conducted a caterpillar plot analysis on the data to determine the magnitude of the school and household effect on the response variables. Further effects of the variables on the children ability to read was assessed through a Principal Component Analysis that categorically tested effects across the levels and identified key factors that clearly explained variation of behaviour in the explained variable, in this case, the reading scores.

3. Results and Discussion

3.1. Descriptive statistics by school, household, and pupil level

This section explored the three-level data structure: pupils (level 1) in households (level 2) in schools (level 3). It provided structure of observations and breakdown of responses on the predictors of reading ability. The predictors focus on school and household factors.

Table 1: Descriptive statistics on predictors of reading

	School level		***Household level***		***Pupil level***	
Predictor	***N***	**Percent**	***N***	**Percent**	***N***	**Percent**
Intervention group						
Group A	26	34.2	71	24.32	78	24.38
Group B	13	17.1	80	27.4	85	26.56
Group C	18	23.7	76	26.03	90	28.13
Group D	19	25.0	65	22.26	67	20.94
Times read to at home						
Nobody reads to me at home	33	44.6	112	39.03	119	37.9
once a day	23	31.1	84	29.27	89	28.34
twice a day	14	18.9	58	20.21	66	21.02
three times a day	3	4.1	24	8.36	27	8.6
More than three times a day	1	1.4	9	3.14	13	4.14
None-textbooks						
None	35	47.3	130	45.45	144	45.86
one book	8	10.8	32	11.19	37	11.78
two books	16	21.6	75	26.22	79	25.16
more than two books	15	20.3	49	17.13	54	17.2
Other sources of books						
No where	38	50.7	146	51.05	159	50.64
Library	8	10.7	25	8.74	27	8.6
class teacher	26	34.7	92	32.17	101	32.17
Classmates	3	4.0	23	8.04	27	8.6
Gender of pupil						
Male	27	36.0	124	44.29	136	44.16
Female	48	64.0	156	55.71	172	55.84
School library is well stocked						
Agree	37	48.7	141	49.47	153	49.2
Disagree	39	51.3	144	50.53	158	50.8
Library is well used by teachers and pupils						
Agree	37	48.7	141	49.47	153	49.2
Disagree	39	51.3	144	50.53	158	50.8
Teaching materials are adequate						

Agree	34	44.7	138	51.49	153	52.4
Disagree	42	55.3	130	48.51	139	47.6
Classroom has electricity						
Disagree	76	100.0	285	100	311	100
		M(SD)		Mean		Mean
Age	60	11.1(1.54)	256	11.3(1.12)	280	11.3(1.10)
Height	74	136.6(8.74)	283	131.6(19.24)	310	131.5(19.15)
Head circumference	74	53.2(3.91)	283	50.9(8.95)	311	50.7(9.04)

Data in Table 1 above, showed that pupils were fairly represented across the nutrition intervention groups and across the three levels (school, household and pupil level). 45% of respondents were not read to at home, while 37% of pupils were not read to at pupil level, while 39% are not read to at household level. Only 30% indicated being read to once across the three levels, implying that pupils were not read to as often. 46-50% of observation indicated that pupils do not have access to other textbooks in households and at individual level. Where textbooks were available, 30% of the pupils indicated that they borrowed reading materials from their class teachers. In general, this implied that households do not stock supplementary reading books for pupils to use in improving their reading skills. 64% of girls were recorded at school level, while 55% were recorded at household and pupils' level. Implying that there were more girls traced in the study than boys.

All schools, households and pupils traced and included as respondents in the study had no access to electricity. Implying that any reading practice, was likely during day time, save for those with access to alternative sources of lighting. All respondents were indifferent on availability of libraries, adequacy of teaching resources and utilization of the same with averages around 50% at school, household and individual level respectively. Average height of pupils was at 136cm with an average head circumference of 53cm for a mean age of 11.

3.2. Random Intercept Model

The random effect intercept model was fitted to 320 pupils, nested in 319 households nested in 76 schools. The number of pupils per household ranged from 1 to 2; and the number of pupils per school ranged from 1 to 19. The intercept was found to be 0.0002 (SE = 0.0559). Thus, without adjusting for any predictor, the average pupil is expected to score 0.002 standard errors from 0, within the range of -0.925 to 5.752 standard errors from 0. The between-school; within-school-between-households; and within-households-between-pupil variances were estimated as: 0.005969; 1.19×10^{-19}; and 0.996, respectively. The likelihood ratio test which compared the current model to a single level (linear regression model) showed that the likelihood ratio chi square statistic was not significant at 5% significance level ($\chi^2(2) = 0.00049$, $p = 0.9998$).

3.3. Coverage Intervals

The absolute magnitude of variance components in z_mscores was ± 0.04788581SE. This showed the extent to which the real, observed population matches the ideal or normative population. In this case, the data used in the study showed that there was a 95% probability that the true (unknown) estimate would lie within the interval, given the evidence provided by the observed data.

3.4. Variance Partition Coefficients (VPC)

The relative importance of schools; households and pupils as sources of the total variation of pupil's reading ability was summarised. Results indicated in Table 2 below showed that almost all variation in pupil reading ability was attributed to variation at pupil level, meaning that the variation in the reading scores of pupils did not come from the augmenting factors at school and household level, rather pupil related factors or factors that were related directly to pupils were responsible for the performance of the pupils in their reading ability.

Table 2: Variance partition coefficients (VPC)

Level	VPC
School	3.590e-07
Household	1.427e-32
Pupil	0.99999964

3.5. Intra-class correlation coefficients (ICCs)

Table 3 below showed that the model implied correlation coefficient (similarity) of the observed z_mscores within schools and within households and implied model of the observed z_mscores within schools and within households showed that both the schools and households had the same ICC, which is almost zero, indicating that the effect of household factors and school level factors could not be relied upon, therefore accepting that pupil level factors were the only effect on the their reading scores.

Table 3: Intra-class correlation coefficients (ICC)

Cluster	ICC
School	3.590e-07
Household	3.590e-07

3.6. Predicting school and household effects

Table 4 below presented descriptive statistics for the school and household random effects. School effects ranged from -0.0038 standard deviation units to 0.0039 standard deviation units; and the household effects range from -1.11e-16 standard deviation units to 6.86e-16 standard deviation units.

Table 4: Descriptive on school and household effects

Random effect	***N***	***M***	***SD***	***Min***	***Max***
v_0	76	-2.08E-12	0.001232	-0.00377	0.003929
u_0	292	-2.12E-18	1.18E-16	-1.11E-16	6.86E-16

Results of testing for the normality of the school and household effects showed that effects were approximately normally distributed as the data points lay along the fitted line at 45-degree angle. Likewise, the quantile-quantile plot for school effects showed that the household effects were not normally distributed, having heavier tails than would be expected from a normal distribution.

The caterpillar plot indicated how many schools differed from the average school showed that schools did not differ significantly from the average school, implying that regardless of which school a pupil was enrolled in, their performance in reading scores were not affected, the school level effects did not explain performance of pupils. Likewise, the households studied, did not differ significantly from the average household in terms of pupils' reading ability as presented in the caterpillar plots, indicating and augmenting the finding that experiences for pupils at household level did not explain the variation in their reading scores but pupil related factors. In summary, the likelihood ratio chi square statistic was found not significant; the ICCs were found to be very small at school and household levels, therefore, it can be concluded that z_mscores at these two levels are independent observations. Therefore, a single level model without predictors would be preferred to the three-level model without predictors in explaining variation in reading scores and discussing any augmenting factors that predict pupil reading ability at pupil level.

3.7. Pupils level Model with predictors

To determine factors that predict reading skills acquisition, individual factors such as age, gender, height and head circumference were considered. A random effects model at pupil level regressed the reading ability of pupils (z_mscore), a centered numericized score on reading outcomes across all the reading skills test-itemized in the reading test administered to all pupils. The model was fitted to 260 pupils, nested in 259 households and in 69 schools. The number of pupils per household ranged from 1 to 2; and the number of pupils per school ranged from 1 to 15. Just like the three-level model without predictors, the three level model with pupil level predictors showed that a likelihood ratio test was not significant at 95% confidence interval, indicating that a linear regression model with predictors at pupil level would better fit the data than the three-level model with predictors ($\chi 2(2) = 0.10$, $p = 0.9505$).

3.8. Household level Model

At the household level, a Principal Component Analysis (PCA) of factors that greatly affect reading outcomes was conducted. Results of the PCA are presented below:

Table 5: PCA results at household level

Principal components/ covariance			Number of obs	298	
			Number of comp.	4	
			Trace	11.06474	
			Rho	0.7301	
Rotation: (unrooted = principal)					
Component	Eigenvalue	Difference	Proportion	Cumulative	
Comp 1	3.50925	1.47695	0.3172	0.3172	
Comp 2	2.0323	0.634066	0.1837	0.5008	
Comp 3	1.3924	0.259427	0.1264	0.6272	
Comp 4	1.39324	0.232096	0.1264	0.7301	
Comp 5	0.906715	0.206939	0.1029	0.8121	
Comp 6	0.699776	0.176771	0.0819	0.8753	
Comp 7	0.523005	0.0775938	0.0632	0.9226	
Comp 8	0.445411	0.18711	0.0473	0.9628	
Comp 9	0.258302	0.105375	0.0233	0.9862	
Comp 10	0.152926		0.0138	1	
Principal (eigevectors)	Components				
Variable	Comp 1	Comp2	Comp3	Comp4	Unexplained
Nutrition Group	-0.0802	-0.048	-0.3073	0.8973	0.06932
Nursery attendance	-0.0472	0.0066	-0.0165	-0.009	0.2483
Meals taken per day	0.0006	-0.0127	-0.003	0.0711	0.435
language	-0.016	0.0114	0.0065	-0.002	0.1825
School absence	-0.4656	0.8764	0.064	0.0497	0.0058
Reading homework	0.3877	0.21	-0.1439	0.1714	0.6207
Who reads to pupils	0.539	0.3385	-0.6309	-0.2123	0.1238
Supplementary reading materials	0.4055	0.0959	0.4603	0.3342	0.3491

Source of reading materials	0.354	0.2131	0.4377	0.0004	0.3715
Environment for reading	0.2089	0.1266	0.281	0.0333	0.5801

The results above showed that the intervention group where the pupil belonged, whether a pupil is read to at home, whether the household has other sources of textbooks, and other books were identified to greatly influence reading abilities of pupils in the household. The selection was based on large eigenvalues exhibited after the PCA was conducted and as shown in Table 5 above. Based on the PCA selection of factors above, the selected factors were included in the model at household level as presented in the regression results in Table 6 below

Mixed-effects ML regression Number of obs 253

Observations per group

Group Variable	**No of Groups**	**Minimum**	**Average**	**Maximum**
Schools	68	1	3.7	15
Households	252	1	1	2

		Wald chi2(8)	34.57
Log likelihood	-347.455	Prob > chi2	0

z_mscore	**coef.**	**std.Err.**	**z**	**P>|z|**	**(95% Conf. Interval)**	
Age	0.661964	0.05407	1.22	0.221	-0.0397789	0.172172
Gender	-0.03367	0.119547	-0.28	0.778	-0.2679746	0.20064
Height	0.001677	0.003758	0.45	0.655	-0.0056888	0.009043
Head Circumference	0.00194	0.007917	0.25	0.806	-0.0135767	0.017456
Nutrition Group	-0.12183	0.058147	-2.1	0.036	-0.2358004	-0.00787
Reading homework	-0.19234	0.055971	3.44	0.001	0.0826343	0.302038
Supplementary readers	0.150648	0.057896	2.6	0.009	0.03717338	0.264123
Sources of readers	-0.04533	0.064842	-0.7	0.485	-0.1724174	0.08176
Constatnt	-1.0412	0.781384	-1.33	0.183	-2.572686	0.490283

Effects Parameters	Estimate	Std. Err.	[95% conf. Interval]	
School				
Var(_cons)	0.021562	0.038219	0.0006683	0.6957332
Household				
Var(_cons)	1.87E-10	5.59E-10	5.30E-13	6.59E-08
Var (Residual)	0.892568	0.086268	0.738532	1.078726

LR test vs. linear regression: chi2(2)=0.39 Prob>chi2 = 0.824

Notably, the model was fitted to 253 pupils, nested in 252 households nested in 68 schools. The number of pupils per household ranged from 1 to 2; and the number of pupils per school ranged from 1 to 15. The three-level model with pupil and household predictors at household level shows that a likelihood ratio test is also not significant at 5% significance level ($\chi2(2) = 0.39$, $p = 0.8248$), Therefore, results indicated that a linear regression model with pupil and household predictors at household level would better fit the data than the three-level model with pupil and household predictors at the same level.

3.9. School level Model

Another PCA was conducted to find out factors that greatly affect ability of students to read at school level. Results of the PCA showed that well stocked school library, well used library, and adequacy of teaching materials in schools explain variance in the ability of pupils to acquire reading skills. Therefore, these factors were included together with others tested at household and pupil level and regressed against outcome scores of the reading test numericized in z_scores.

The selection of the factors included in the mixed effects mode was based on their large eigenvalues. The regression output in Table 7 below included factors at pupil, school and household factors to test whether these factors significantly explain how well pupils learn to read.

Mixed-effects ML regression			Number of obs.	230		
Group Variable	No. of Groups		Observations per group			
		Minimum	Average	Maximum		
Schools	68	1	3.4	13		
Households	229	1	1	2		
log likelihood	-311.11372		Wald chi2 (10)	40.98		
			Prob > chi2	0		
Z_mscore	Coef.	Std. Err.	z	P>|z|	[95% conf. Interval]	
Age	0.0770659	0.560734	1.37	0.169	-0.03284	0.186968
Gender	-0.1342454	0.122392	-1.1	0.273	-0.37413	0.105638
Height	-0.0067225	0.004751	-1.41	0.157	-0.01603	0.002589
Head Circumference	0.029429	0.013095	2.25	0.025	0.003764	0.055094
Nutrition Group	-0.169909	0.061183	-2.78	0.005	-0.28983	-0.04999
Reading homework	0.1805176	0.059149	3.05	0.002	0.064588	0.296448
Supplementary readers	0.1019654	0.061352	1.66	0.097	-0.01828	0.222212
sources of readers	-0.0174194	0.067558	-0.26	0.797	-0.14983	0.114992
well stocked school library	-0.2618095	0.182951	-1.43	0.152	-0.62039	0.096768
Adequacy of teaching materials in schools	0.0094144	0.172321	0.05	0.956	-0.32833	0.347157
_cons	-1.096159	0.845345	-1.3	0.195	-2.753	0.560686

Random-effects parameters	Estimate	Std. Err	95% Conf. Interval	
Schools				
Var (_cons)	2.64E-12	6.19 e-09		0
Household				
Var (_cons)	1.21E-15	4.01E-15	1.83E-18	8.01E-13
Var (residual)	0.8758676	0.081873	0.7292407	1.051976

The model was fitted to 230 pupils, nested in 229 households nested in 68 schools. The number of pupils per household ranged from 1 to 2; and the number of pupils per school ranged from 1 to 13. Just like the three-level model without pupil predictors, the three level model with pupil level, household level, and school level predictors at school level shows that a likelihood ratio test is also not significant at 5% significance level ($\chi2(2)=0.00$, $p = 1.000$), indicating that a linear regression model with pupil, household, and school predictors at school level would better fit the data than the three-level model with similar predictors at school level.

Adding household level random effects to the school level model with predictors at all levels having included all factors that affect reading abilities based on the PCA at pupil, household and school level and found out that they do not significantly explain how well pupils read. Household random effects were added to the school level model with predictors at all levels to find out how they affect other factors tested above in influencing how well pupils read. A linear regression test through a mixed effect model was then carried out to test the contribution of the household random effects at school level and all other predictors across the levels.

The model was fitted to 230 pupils, nested in 229 households nested in 68 schools. The number of pupils per household ranged from 1 to 2; and the number of pupils per school ranged from 1 to 13. Adding household level random effects to the school level model with predictors at all levels showed a significant likelihood ratio test at 5% significance level ($\chi2(2) = 15.86$, $p = 0.0078$), indicating that the random effects model at school level with predictors at all levels and a random effect at household level would better fit the data than single-level model with predictors at all levels.

The model has shown that, holding other variables at their mean, the nutritional supplementation interventions; number of times a pupil reads at home and school library being well stocked would significantly predict pupil's ability to read at 95% significance level as their p values have been found to be less than 0.05. changing from a well-stocked library to a poorly stocked library would decrease the standardized score of the pupil's average score by a factor of 0.36.

The Likelihood-ratio test provides evidence that household level heterogeneity varies across the study conditions ($\chi2(13) = 300.75$, $p < 0.001$). Augmenting that random nutrition intensity group which a pupil belonged would affect ability of the pupil to read, in addition to factors such as number of times a pupil reads at home and school library being well stocked.

Increased nutritional supplementation had a statistically significant effect on reading ability of pupils in primary schools. Particularly, a pupil who switched from higher nutritional supplementation group a to nutrition intensity group resulted in a corresponding decrease in the standardized score of their average score by a factor of 0.15 (Adj. $\beta = 0.022$; 95% CI: 0.282 to 0.0224). In addition, pupils who received delayed supplementation (variance= 0.9563, SE=0.3372) varied greatly in their performance and reading scores, compared to those in other interventional groups. This implied that those in groups with greater nutrition intensity performed better and the difference in performance within the groups was less significant. The ANOVA on *z_mscores* and various intervention levels did not greatly fit the data (Large Root MSE), however, the total variation on performance of groups at model level was significant ($p=0.038<p=0.05$). This implied that within the nutrition groups, a clear variation significance was found on the intervention group with delayed nutrition supplementation ($p=0.0461 < p=0.05$), augmenting earlier findings on greater variation in performance for pupils randomly selected in the delayed nutrition supplementation group.

4. Conclusion

Intensity of nutrition that a pupil takes in early years affect their ability to acquire reading skills. This is augmented by the number of times a pupil practice reading and availability of textbooks to read, including well stocked and utilized libraries available in schools where pupils are enrolled. The homogeneity in school resources and household characteristics leaves no marked effect on the variation of pupil scores. Therefore, while it is critical to resource variables that affect the teaching of reading at school and household level, factors that directly affect a pupil in attaining reading instruction are the most critical and have marked effects on the teaching of reading, including early nutrition status of pupils undertaking a reading instruction. These findings challenge the implementers of reading interventions to go beyond investing in reading instruction, and consider integrating nutrition support of pupils, early in their lives, populating homes with supplementary readers, and working with community platforms to support after-school reading practice and homework to ensure that reading skill gains obtained from the reading instruction are sustained and elevated.

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