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MULTIVARIATE ANALYSIS OF VARIANCE (MANOVA) AND HOTELLING ANALYSIS ON SCHOOL FEEDING PROGRAM IN KADUNA STATE, NIGERIA

M.O. Adenomon, N.O. Nweze, *M.B. Audu, Abubakar Muhammad Auwal

Department of Statistics and Data Analytics, Nasarawa State University, Keffi

*Corresponding Author Email Address: abvuan@gmail.com

ABSTRACT

Gender disparities in education remain a major challenge in sub-Saharan Africa, with girls disproportionately affected by socioeconomic barriers to schooling. In response, governments and development partners have implemented school feeding programs (SFPs) as incentives to improve access and retention. Secondary data from 16 selected public primary schools in Chikum Local Government Area of Kaduna State, covering three years before (2012-2014) and three years after (2016-2018) the introduction of the SFP, were analysed using Hoteling's T^2 test and Multivariate Analysis of Variance (MANOVA) to assess male and female enrolment trends jointly. The analytical framework treated male and female enrolment as a bivariate $(\mathrm{p} = 2)$ response vector, with a two-group design (before vs after SFP) yielding $\mathrm{g} = 2$ groups, $\mathrm{n} = 6$ year-level observations, and $\mathrm{s} = \min(\mathrm{p}, \mathrm{g} - 1) = 1$ discriminant dimension. Findings revealed a statistically significant increase in joint enrolment following the introduction of SFP The Hoteling's T^2 statistic $(\mathrm{T}^2 = 132.88, \mathrm{F}92, 3) = 49.83, \mathrm{p} = 0.005)$. Female enrolment recorded a larger proportional gain (34%) thsn male enrolment (20%), suggesting that the SFP contributed to narrowing the gender gap in primary school participation. The study recommends sustained funding, community engagement, and integration with complementary educational interventions to consolidate program gains.

Keywords: school feeding program, gender equity, primary education, enrolment, Hoteling's T^2, MANOVA, Kaduna State

INTRODUCTION

Globally, access to education has expanded significantly in recent decades, yet millions of children remain excluded, with gender disparities persisting across many developing regions. The United Nations Educational, Scientific and Cultural Organisation (UNESCO, 2022) reported that 244 million children and adolescents were out of school in 2021, with sub-Saharan Africa accounting for the largest share. Girls are disproportionately affected due to entrenched socio-cultural practices, economic hardship, and gendered household responsibilities. These barriers undermine progress toward Sustainable Development Goal 4 (SDG4), which calls for inclusive and equitable quality education for all (UNESCO, 2022).

One policy instrument that has gained global traction is the School Feeding Program (SFP), which provides meals to school-aged children to enhance nutrition, increase attendance, and reduce dropout rates. Today, SFPs reach more than 388 million children worldwide, making them the largest social safety net in education (World Food Program, 2020). Beyond alleviating hunger, SFPs reduce opportunity costs for families, serving as strong incentives for school participation. Systematic reviews confirm that SFPs have measurable positive effects on enrolment, retention, and cognitive performance (Kristjansson, Francis, Liberato, & Greenhalgh, 2019).

In Sub-Saharan Africa, where poverty and food insecurity are prevalent, SFPs are particularly critical. Evidence suggests that such interventions not only increase overall enrolment but also have a disproportionately greater impact on girls, who face higher risks of exclusion. Nigeria continues to contend with one of the world's largest populations of out-of-school children, with over ten million, with girls disproportionately excluded (UNICEF, 2021). In 2016, the Federal Government of Nigeria launched the Home-Grown School Feeding Program (HGSFP) to provide daily meals to primary school pupils, thereby boosting enrolment, retention, and child nutrition.

Despite documented enrolment, gains, and gender-disaggregated empirical analyses of the program's impact, these remain limited, particularly for Kaduna State and the Chikun Local Government Area (LGA). Existing studies have mostly aggregated outcomes without distinguishing male from female pupils and have relied predominantly on descriptive methods. This study addresses that gap by employing Hoteling's T^2 and MANOVA, which are methods appropriate for jointly testing changes in a bivariate enrolment response (male and female counts simultaneously) to determine whether the SFP led to greater gains for girls relative to boys.

Primary education is a fundamental right for every school-age child (UNESCO, 2022). For any educational system to be efficient, there should be a smooth transition of pupils from one level to the next, with 100% retention, completion, and satisfactory educational performance (Psacharopoulos, 1980). Enrolment and completion rates remain low in developing countries, contributing to high levels of illiteracy. The major problem affecting school-going children in primary schools, especially in low-income areas, is poverty. Since the SFP was introduced in Kaduna State, there has not been sufficient rigorous statistical research to assess its impact on gender-disaggregated enrolment using multivariate methods.

This study investigates the impact of the School Feeding Program (SFP) on primary school enrolment in Chikun LGA, Kaduna State. Specifically, it examines whether the program produced a statistically significant joint change in male and female enrolment using Hotelling's T^2 test; whether mean enrolment vectors differed between the pre-SFP period (2012–2014) and the post-SFP period (2016–2018) through MANOVA; and whether the program had a proportionally greater effect on female enrolment, thereby contributing to reducing the gender gap in school participation. Enrolment was selected as the primary outcome because

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complete, gender-disaggregated records were available for the study period. While retention, completion, and economic outcomes remain important dimensions of SFP impact, they require longitudinal pupil-level data that are not available for this analysis. Future research should extend this framework to those outcomes as data availability improves.

School feeding programs (SFP)have become one of the most widely adopted interventions for addressing child hunger, malnutrition, and educational deprivation worldwide. According to the World Food Programme (2020), SFPs reach over 388 million children, making them the largest social safety net in the education sector. Kristjansson *et al.* (2019), in a Cochrane systematic review, concluded that children receiving school meals are more likely to attend school regularly and less likely to drop out. The potential of SFP to address gender disparities has attracted increasing scholarly attention, as programmes that combine on-site meals with take-home rations often report stronger outcomes for girls, as families are further incentivised to keep daughters in school (Gelli, Aurino, Folson, Arhinful, Adamba, Osei-Akoto, Masset, Watkins, Fernandes, Drake, & Alderman, 2019)

In Nigeria, Alabi and Ibrahim (2024) found that the HGSFP increased female enrollment in Gombe Metropolis, with particularly strong effects in lower primary grades. Similarly, the program reported gains in enrolment at the national level (Akanbi & Alayande, 2021). Notwithstanding these findings, most existing studies aggregate outcomes without rigorously testing for statistically significant gender-differentiated impacts using multivariate methods, which is a gap the present study directly addresses by applying Hoteling's T^2 and MANOVA to gender disaggregated school level data.

MATERIALS AND METHODS

Research Design and Data

This study employed a quantitative ex post facto comparative design. Secondary data on the annual enrolment of male and female pupils were obtained from school records and official statistics provided by the Kaduna State Universal Basic Education Board (SUBEB) for 16 public primary schools in the Chikun Local Government Area (LGA) that participated in the SFP. The study period spans two phases (before SFP that is 2012, 2013, and 2014, and after SFP (2016, 2017, 2018), which yielded $n = 6$ annual observations in total.

Variables

The dependable variable vector is bivariate ($p = 2$)

$$Y = (y_1, y_2)^T \qquad (1)$$

where y_1, denotes total number of male enrolment and y_2, denotes total female enrolment for each year. The grouping (independent) variable is SFP phase; Group 1 = Before SFP ($n_1 = 3\ years$) and Group 2 = After SFP ($n_2 = 3\ years$). This yields a two-sample design with $g = 2$ groups, $p = 2$ response variables, and $s = min(p, g-1) = min(2,1) = 1$ discriminant dimension.

Statistical Model Definition

MANOVA Model

The one-way MANOVA model for the $j-th$ observation in group i is:

$$\boldsymbol{Y}_{ij} = \boldsymbol{\mu} + \boldsymbol{\tau}_i + \boldsymbol{\varepsilon}_{ij} \qquad (2)$$

Where $\boldsymbol{Y}_{ij}$ is the $(p \times 1) = (2 \times 1)$ observation vector for year j in phase i; $\boldsymbol{\mu}$ is the (2×1) grand mean vector, $\boldsymbol{\tau}_i$ is the (2×1) treatment effect vector for phase i subject to $\sum_i n_i \boldsymbol{\tau}_i = 0$ and $\boldsymbol{\varepsilon}_{ij} \sim N_2(0, \Sigma)$ is the (2×1) error vector with common covariance matrix Σ.

In matrix form:

$$\boldsymbol{Z} = \boldsymbol{XB} + \boldsymbol{E} \qquad (3)$$

Where $\boldsymbol{Z}$ is the $(n \times p) = (6 \times 2)$ response data matrix, $\boldsymbol{X}$ is the $\left(n \times (g+1)\right) = (6 \times 3)$ design matrix: $\boldsymbol{B}$ is the $\left((g+1) \times p\right) = (3 \times 2)$ matrix of parameters: and $\boldsymbol{E}$ is the $(n \times p) = (6 \times 2)$ matix of error vectors**.** Note that $\boldsymbol{\varepsilon}_{ij}$ denotes error vectors (not eigenvectors)

Hypothesis

The null and alternative hypotheses are:

$$H_0 = \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2 \qquad (4)$$

$$H_0 = \boldsymbol{\mu}_1 \neq \boldsymbol{\mu}_2 \qquad (5)$$

Where $\boldsymbol{\mu}_1 = (\boldsymbol{\mu}_1 M, \boldsymbol{\mu}_1 F)^T$ is the mean vector of (male and female) enrollment before SFP, and $\boldsymbol{\mu}_2 = (\boldsymbol{\mu}_2 M, \boldsymbol{\mu}_2 F)^T$ is the corresponding vector after SFP. Rejection of H_0 implies that the joint enrolment profile changed significantly following SFP introduction.

Sum of Squares and Cross Products (SSCP) Partition

The total SSCP matrix $\boldsymbol{T}$ partitions into between-group (**B**) and within-group (**W**) components:

$$\boldsymbol{T} = \boldsymbol{B} + \boldsymbol{W} \qquad (6)$$

$$\boldsymbol{B} = \textstyle\sum_i n_i (\bar{y}_i - \bar{y})(\bar{y}_i - \bar{y})^T \qquad (7)$$

$$\boldsymbol{W} = \textstyle\sum_i \sum_j \left(Y_{ij} - \bar{y}_i\right)\left(Y_{ij} - \bar{y}_i\right)^T \qquad (8)$$

With $g = 2, p = 2$, and $n = 6$: $\boldsymbol{B}$ has $df = g - 1 = 1$, and $\boldsymbol{W}$ has $df = n = 4$. Both $\boldsymbol{B}$ and $\boldsymbol{W}$ are symmetric (2×2) matrices.

MANOVA Test Statistics

Since $s = min(p, g-1) = 1$, all four multivariate test statistics reduce to a single eigenvalue λ_1, of $\boldsymbol{W^{-1}B}$, and all yield numerically equivalent F-values. Let

$$\lambda_1 = largest\ eigenvalue\ of\ \boldsymbol{W^{-1}B} \qquad (9)$$

Wilks' Lambda:

$$\boldsymbol{\Lambda} = \frac{|\boldsymbol{W}|}{|\boldsymbol{B} + \boldsymbol{W}|} = \frac{\mathbf{1}}{(\mathbf{1} + \lambda_1)} \qquad [for\ s = 1] \qquad (10)$$

Pillai's Trace

$$\boldsymbol{V} = \frac{\lambda_1}{\mathbf{1} + \lambda_1} = 1 - \boldsymbol{\Lambda} \qquad (11)$$

Hoteling-Lawley Trace:

$$\boldsymbol{T^{2*}} = \lambda_1 \qquad [for\ s = 1] \qquad (12)$$

Roy's Greatest Root:

$$\boldsymbol{\theta} = \frac{\lambda_1}{\mathbf{1} + \lambda_1} = Pillai's\ Trace \qquad [for\ s = 1] \qquad (13)$$

When $s = 1$, all four statistics are equivalent and yield the same F-value. This equivalence is verified in the results of the present study (all F=49.83). for $s = 1$, the exact F-statistic is:

$$F = [(n - g - p + 1)/p] \times \lambda_1 \sim F(p, n - g - p + 1) \qquad (14)$$

Here $p = 2, n = 6, g = 2$, so $F(2,3)$ with $df_1 = p = 2$ and $df_2 = n - g - p + 1 = 6 - 2 - 2 + 1 = 3$

Hoteling's T^2 Test

For the two-sample case (before vs after), Hoteling's T^2Statistic

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test $H_0 = \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$ and is defined as:

$$T^2 = [n_1 n_2/(n_1 + n_2)] \times (\bar{y}_1 - \bar{y}_2)^T Sp^{-1}(\bar{y}_1 - \bar{y}_2) \quad (15)$$

Where the pooled covariance matrix is:

$$Sp = \frac{[(n_1 - 1)S_1 + (n_2 - 1)S_2]}{n_1 + n_2 - 2} \quad (16)$$

Moreover, S_1 and S_2 are the (2×2) sample covariance matrices for the before-SFP and after-SFP periods ,r respectively The T^2 statistic converts to an exact F-statistic:

$$F = [(n_1 + n_2 - p - 1)/p(n_1 + n_2 - 2)] \times T^2 \sim F(p, n_1 + n_2 - p - 1) \quad (17)$$

With $n_1 = n_2 = 3$ and $p = 2$: $F \sim F(2,3)$, as can be seen in the reported degrees of freedom in Table 4.4.

Relationship between $T^2$and MANOVA: for $g = 2$ groups, the one-way MANOVA is algebraically equivalent to the two-sample Hotelling'sV test. In this study, both procedures yield identical F-values ($F = 49.83$) because the same data and the same s=1 discriminant structure underlie both computations. Reporting both is appropriate as MANOVA provides the broader multivariate framework (SSCP) decomposition, all four test criteria) while V provides the direct two-sample interpretation.

Effect Size

The effect size associated with Wilk's Lambda Λ is partial eta squared:

$$\eta_p^2 = 1 - \Lambda = 1 - 0.0292 = 0.9708 \quad (18)$$

By Cohen's (1988) conventions ($\eta_p^2 = 0.01\ small: 0.06\ medium: 0.14\ large$), $\eta^2 p = 0.97$ represents a very large effect, indicating that SFP phase accounts for 97.1% of the variance in the joint male-female enrolment vector.

The Mahalanobis distance between the two group mean vectors is:

$$D^2 = (\bar{y}_1 - \bar{y}_2)^T Sp^{-1}(\bar{y}_1 - \bar{y}_2) = T^2(n_1 + n_2)/(n_1 n_2) \quad (3.19)$$

RESULTS AND DISCUSSION

Overall enrollment trends

Table 1 presents total enrolment disaggregated by gender across the six years under review. Average total enrolment before SFP $(2012 - 2014)$ was $36{,}050$ pupils, rising to $45{,}783$ after SFP (2016–2018), a 27% increase. Male enrolment increased from a mean of $18{,}733$ to $22{,}546$ (approximately 20%), while female enrolment recorded a larger gain from $17{,}317$ to $23{,}237$ (approximately 34%). Female enrolment, which lagged behind male enrolment before the program, surpassed male enrolment across all three post-SFP years.

Table 1: Overall enrolment of pupils before and after SFP in Chikun LGA. Source: Kaduna State SUBEB.

Year	Total enrolment	Male enrolment	Female enrolment
Before SFP			
2012	34,600	18,100	16,500
2013	35,950	18,700	17,250
2014	37,600	19,400	18,200
Mean (before)	**36,050**	**18,733**	**17,317**
After SFP			
2016	46,017	22,983	23,034
2017	45,210	22,064	23,146
2018	46,123	22,591	23,532
Mean (after)	**45,783**	**22,546**	**23,237**
% change	**+27%**	**+20%**	**+34%**

Descriptive statistics of the bivariate response vector

Table 2 presents the means and standard deviations of both components of the bivariate response vector (y_1, y_2). Female enrolment recorded a larger mean gain ($5{,}920.67\ vs. 3{,}812.67$) and also became more stable post-SFP, as evidenced by the reduction in SD from $851.96\ to\ 261.26$.

Table 2: Descriptive statistics of the bivariate response vector before and after SFP ($\mathrm{n}_1 = \mathrm{n}_2 = 3$).

Variable	Before SFP mean	After SFP mean	Mean difference	Before SFP SD	After SFP SD
Male enrolment (y_1)	18,733.33	22,546.00	+3,812.67	650.64	461.15
Female enrollment (y_2)	17,316.67	23,237.33	+5,920.67	851.96	261.26

The before-SFP and after-SFP group mean vectors are:

$$\bar{y}_1 = (18{,}733.33, 17{,}316.67)^T \text{ and } \bar{y}_2 = (22{,}546.00, 23{,}237.33)^T \quad (20)$$

The mean difference vector is:

$$\boldsymbol{d} = \bar{y}_1 - \bar{y}_2 = (3{,}812.67, 5{,}920.67)^T \quad (21)$$

Hotelling's T² results

Table 3 presents the two-sample Hoteling's T² results testing H_0: $\boldsymbol{\mu}_1 = \boldsymbol{\mu}_2$.

Table 3: Hotelling's T² multivariate test ($\mathrm{n}_1 = \mathrm{n}_2 = 3, \mathrm{p} = 2$). $\mathrm{p} < .01 \rightarrow \text{reject } \mathrm{H}_0$.

Test statistic	Value	df_1	df_2	$p-value$
Hoteling's T²	132.88	—	—	—
Equivalent $F = T^2 \times [(n_1 +$	49.83	2	3	.005

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Test statistic	Value	df_1	df_2	$p - value$
$n_2 - p - 1) / p(n_1 + n_2 - 2)]$				

The T² statistic was 132.88. Applying Equation 3.17: $F(2,3) = [(3+3-2-1) / 2(3+3-2)] \times 132.88 = (2/8) \times 132.88 = 49.83, p = 0.005 < 0.01$. H_0 was rejected: the combined (male, female) enrolment mean vector differed significantly between the two periods.

MANOVA results
Table 4 presents all four MANOVA test statistics. Since $s = 1$, all are equivalent and yield the same $F - value$, consistent with Equations $10 - 13$.

Table 4: MANOVA results — group effect (before SFP vs. after SFP). All four statistics equivalent when s = 1. $\eta^2_p = 1 - \Lambda$. Correction from original: Roy's Greatest Root $\theta = \lambda_1/(1+\lambda_1) = 33.2203/34.2203 = 0.9708$ (original paper incorrectly reported 33.2203).

Test statistic	Value	Num df	Den df	F	p	η^2_p
Wilks' Lambda (Λ)	0.0292	2	3	49.83	.005	0.9708
Pillai's Trace (V)	0.9708	2	3	49.83	.005	0.9708
Hoteling–Lawley Trace (T²*)	33.2203	2	3	49.83	.005	0.9708
Roy's Greatest Root (θ)	0.9708	2	3	49.83	.005	0.9708

Note: Wilks' $\Lambda = 1/(1+\lambda_1) = 0.0292$; Pillai's Trace $= 1 - \Lambda = 0.9708$; $T^2 * = \lambda_1 = 33.2203$; $Roy's\ \theta = \lambda_1/(1+\lambda_1) = 0.9708 =$ Pillai's Trace exactly. The equality of all four F-values is a mathematical certainty when s = 1, not a coincidence. This makes all four F-values identical.
The effect size $\eta_p^2 = 0.9708$ indicates that the SFP phase explains about 97.1% of the variance of the joint enrolment vector. This is a very large effect according to Cohen's (1988) conventions. H_0 is rejected: the multivariate enrolment profile changed significantly following SFP introduction.

Class-level enrollment

Table 5: Class-level enrolment before and after SFP for Primary 1 – Primary 3). Source: Kaduna State SUBEB

Class	Year	Male	Female
Primary 1	2012	7,800	7,200
	2013	8,050	7,450
	2014	8,300	7,800
	2016	9,898	9,971
	2017	8,566	8,860
	2018	8,656	8,992
Primary 2	2012	5,600	5,100
	2013	5,750	5,300
	2014	5,900	5,600
	2016	6,881	6,943
	2017	7,498	8,087
	2018	7,188	7,500
Primary 3	2012	4,700	4,200
	2013	4,900	4,500
	2014	5,200	4,800
	2016	6,204	6,120
	2017	6,000	6,199
	2018	6,747	7,040

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DISCUSSION
The descriptive statistics revealed that while both male and female enrolment increased after the introduction of the SFP, the gains were proportionally larger for females $(+34\%)$ than for males $(+20\%)$, echoing findings from comparable studies in sub-Saharan Africa (Gelli et al., 2019; Au $et\ al$ 2020). The Hoteling's T^2 test $(T^2 = 132.88, F(2,3) = 49.83, p = 0.005)$ confirmed that this joint shift in the (male, female) enrolment vector was statistically significant. MANOVA corroborated this conclusion across all four test criteria.
The analytical design is a two-group comparison (before vs. after SFP) on a bivariate outcome (male and female enrolment jointly), analyzed at the year level of observation $(n_1 = n_2 = 3)$. The use of Hoteling's T^2 and MANOVA is specifically justified because the research objectives concern the *joint* change in male and female enrolment simultaneously, not each gender in isolation. For $g = 2$ groups, both procedures are algebraically identical — their common F (49.83) is a mathematical identity that is true

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whenever $s = min(p, g-1) = 1$.

CONCLUSION AND RECOMMENDATIONS

This study examined the joint effect of the School Feeding Program on male and female enrolment in public primary schools in Chikun LGA, Kaduna State. A bivariate response vector (y_1 = male enrolment, y_2 = female enrolment) was analyzed using Hoteling's T² and one-way MANOVA, with both procedures yielding $F(2,3) = 49.83, p = 0.005$ due to the $s = 1$ discriminant structure of the two-group, two-variable design. The null hypothesis of equal mean vectors was rejected, confirming a statistically significant multivariate change in enrolment after SFP introduction. Female enrolment gained disproportionately $(+34\%)$ relative to male enrolment $(+20\%)$, and female enrolment surpassed male enrolment in all three post-SFP years. The SFP is considered an effective policy tool for increasing total enrolment and promoting gender equity in primary education. The study advances the following core recommendations:

1. Build on the gains in enrolment achieved so far by scaling up the SFP to all primary levels.
2. Build on the gains in gender equity by providing targeted support for girls – learning materials, sanitation facilities and community sensitization campaigns.
3. Develop a strong monitoring and evaluation framework with gender-disaggregated reporting to monitor enrolment, retention and completion rates over time.
4. School-level data should be used in future longitudinal studies to facilitate stronger causal identification of program impacts through the use of school-fixed-effects modelling.
5. Integrate the SFP with larger educational interventions, like infrastructure, teacher training and curriculum improvement, to maximize impact on learning outcomes.

REFERENCES

Akanbi, G. O., & Alayande, T. (2021). Evaluating the effect of home-grown school feeding program on school enrolment in Nigeria. *Cogent Social Sciences, 7*(1), 1935097.

Alabi, A., & Ibrahim, S. (2024). School feeding program as a determinant of enrolment, attendance, and academic performance in Gombe Metropolis. *Kano Journal of Educational Studies, 14*(1), 45–62.

Aurino, E., Tranchant, J. P., Sekou Diallo, A., & Gelli, A. (2020). School feeding or general food distribution? *Global Food Security, 25*, 100433.

Bundy, D. A. P., D. A. P., de Silva, Nilanthi, N., Horton, Susan, S., Jamison, Dean T., D. T., & Patton, George C., G. C. (Eds.). (2018). *Re-imagining school feeding: A high-return investment in human capital and local economies*. The World Bank.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates.

Gelli, A., Aurino, E., Folson, G., Arhinful, D., Adamba, C., Osei-Akoto, I., Masset, E., Watkins, K., Fernandes, M., Drake, L., & Alderman, H. (2019). *A school meals program implemented at scale in Ghana increases height-for-age during midchildhood in girls and in children from poor households: A cluster randomized trial*. *Journal of Nutrition, 149*(8), 1434–1442. https://doi.org/10.1093/jn/nxz079

Johnson, R. A., & Wichern, D. W. (2007). *Applied multivariate statistical analysis* (6th ed.). Pearson.

Kristjansson, E., Francis, D., Liberato, S., & Greenhalgh, T. (2019). School feeding for improving the physical and psychosocial health of disadvantaged elementary school children. *Cochrane Database of Systematic Reviews, 2019*(7), CD012736.

Olatunde, A., Nnam, N. M., & Okeke, E. C. (2023). Headteachers' perceptions of the Nigerian home-grown school feeding program in Enugu State. *BMC Nutrition, 9*, 95.

Psacharopoulos, G. (1988). Education and development: A review. *World Bank Research Observer, 3*(1), 99–116.

Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics* (7th ed.). Pearson.

UNESCO. (2022). *Global education monitoring report 2022: Gender report.* Paris: UNESCO.

UNICEF. (2021). *Situation of children in Nigeria.* United Nations Children's Fund.

World Food Program. (2020). *State of school feeding worldwide 2020.* Rome: WFP.