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Full Length Research

Relationship between food security, dietary diversity, nutrient adequacy and body composition of farmers in South East, Nigeria

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ABSTRACT: Excess weight (overweight and obesity) is on the rise and is mainly linked to unhealthy diets. To cope with rising food inflation, individuals often resort to cheap energy-dense foods. The cross-sectional descriptive study examined the relationship between food security, dietary diversity, nutrient adequacy and body composition of farmers in Southeast, Nigeria. Multi-stage sampling was used to select participants, and Pearson correlation was used to determine relationships. International Business Machine Statistical Package version 25 was used for the statistical analysis, and significant levels were judged at $p \leq 5$. The linear relationship between food insecurity experience scale scores showed a weak but significant negative relationship with total body water (r=-0.26, p=0.000). A weak positive significant relationship existed between dietary diversity scores and muscle mass (r=.06, p=0.036). But mean adequacy ratios exhibited strong and weak positive relationships with body water (r=0.12, P=0.000) and body muscle mass (r=0.08, P=0.005), respectively. Positive significant (r=0.57, p=0=0.000) relationship existed between weight and BMI and that between weight and visceral fat was weak positive and significant (r=0.42, p=0.000), as well as weight and body water (r=0.36, p=0.000). Relationship between Weight and BMM was weak negative and significant (r=-14, p=0.000). A strong positive significant (r=.70, p=0.000) relationship was noted between BMI and body fat, while that between BMI and BMM was moderate negative and significant (r=-0.48, p=0.000). Body fat and visceral fat were moderately positive and significant (r=.48, p=0.000), and for body fat and BMM, it was strongly negative and significant (r=-80, p=0.000). This shows that nutrient-dense foods can improve nutrient intakes, which subsequently improve health. Thus, strategies to improve food security, dietary diversity and nutrient adequacy should be implemented for optimum nutrition and health of the farmers and the entire populace at large.

Keywords: Body composition, dietary diversity, food security, nutrient adequacy.

INTRODUCTION

Overnutrition, particularly excess weight (overweight and obesity) among adults, is rising at an alarming rate and constitutes a major global health challenge (Lin and Li, 2021; World Health Organisation (WHO), 2024). According to the World Obesity Federation (2024), the prevalence of excess weight is higher in low- and middle-income countries (LMICs). Undernourishment, specifically food insecurity, is a potential risk factor for adult malnutrition, and it has been linked with obesity in many countries (Ponce-Alcala *et al*., 2021; Carvajal-Aldaz *et al*., 2022; Brandt *et al*., 2023; Rezaei *et al*., 2024). The association is mainly due to the unaffordability of healthy diets and the prevalence of unaffordability of healthy diets (PUA); the proportion of the population unable to afford even the least-cost option of a healthy diet has risen. Globally, 31.9% or 2,604.6 billion persons were unable to afford a healthy diet in 2024, while the value for Africa was 66.6% or 1.008.9 billion persons. The proportions for Western Africa and Nigeria were 70.0% and 79.3%, respectively (Food and Agriculture Organisation, International Fund for Agricultural Development, World Food Programme & World Health Organisation (FAO, IFAD, WFP & WHO) (2025). This is because the cost of a healthy diet (CoHD) has been increasing steadily, particularly due to food insecurity. For instance, the cost of a healthy diet in 2024 in the world was 4.46 purchasing power parity dollars per person per day. The values for Africa and Nigeria were 4.41 and 4.72PPP dollars per person per day, respectively (FAO *et al*., 2025). Globally, 10.1% were severely food insecure: Africa (22.2%), Western Africa (20.2%, Asia (8.7%), Latin America and the Caribbean (7.8%), Oceania (9.6%) and Northern America and Europe (1.5%) (FAO *et al*., 2025). The National Food Consumption and Micronutrient Survey 2021 reported that 78.7% of households in Nigeria were moderately or severely food insecure, while 22.2 experienced severe food insecurity. In rural areas of Nigeria, 79.0% and 21.6% were moderately and severely or severely food insecure, respectively (Federal Government of Nigeria & International Institute for Tropical Agriculture (FGoN and IITA), 2024).

Food price inflation puts pressure on food security and nutrition outcomes. Inflation erodes the purchasing power of households, making it harder for them to afford daily necessities, particularly food. As a coping mechanism, households may adjust their food consumption pattern, shifting to cheaper, less nutrient-dense foods, reducing diversity and meal frequency or reducing the quantity of food women and children consume (Quisumbing *et al*., 2008; Brinkman *et al*., 2010; Zaman *et al*., 2011). Food cost can be a hindrance to access to and consumption of a healthy diet. This is because nutrient-rich foods such as vegetables, fruit and animal source foods (ASFs) are generally more expensive than starchy staples, oils and sugars (Monteiro *et al*., 2018; Headey and Alderman, 2019). When inflation reduces households or individual's capacity to purchase healthy foods, their consumption is undermined. This subsequently poses serious risks to food security and nutrition outcomes (FAO *et al*., 2025). For instance, in 2021, the average global price of vegetables was 11.9 times higher than that of basic starchy staples, while animal source foods, fruit and legumes were 9.1, 7.2 and 3.1 times more expensive, respectively. Besides, shifts in labour force participation for women in particular have increased demand for convenient, shelf –stable and appealing food options across urban and rural areas globally (Raneri *et al*., 2019; Nguyen *et al*., 2021; Reardon *et al*., 2021; Sauer *et al*., 2021; Popkin and Ng, 2022). Thus, the subsequent increase in the consumption of ultra-processed foods (UPFs) is closely linked to the escalating prevalence of diet—related non-communicable diseases (NCDs) and environmental health (Anastasiou *et al*., 2022; Lane *et al*., 2024). That is often more evident among food-insecure persons, and the difficulty is intensified by social, economic and regional inequalities, especially in low- and middle-income countries (LMICs) (Carvajal-Aldaz *et al*., 2022; FAO *et al*., 2023). Food insecurity is chronic when it persists overtime and it is a less severe form of food insecurity. It does not necessarily threaten lives or livelihoods but can negatively affect people's well-being and long-term development of individuals, households and communities. Thus, the reason why nutrient intakes are negatively affected, resulting to poor nutrition and health.

Nutrient adequacy (adequate in essential nutrients and bioactive compounds important for health) is another universal characteristic of a healthy diet. The rest are diversity (composed of a variety of foods and food groups), balance (across proteins, carbohydrates and fats) and moderation in dietary components that are detrimental to health if consumed in excess (FAO and WHO, 2024). When diets consistently meet these four criteria over time, it ensures positive nutrition outcomes in terms of body composition. The distribution of fat, muscle, bone and other tissues in the human body is termed body composition (Athletic Insight, 2025). Body composition measures the overall health and fitness level in terms of body fat percentages. It changes as an individual ages and typically muscle mass decreases while fat mass increases (Etchison *et al*., 2011). Overweight and obesity have been noted to increase with advancing age. Obesity has been explicitly identified as a chronic disease, and fat location defines its pathogenesis for complications (National Academies of Sciences, Engineering and Medicine (NASEM), 2024). According to Bluher (2020), a continuous positive energy balance that compromises the body's ability to store healthy fat in the adipose tissue depots such as hips, thighs plus ectopic and abdominal fat stores in and around organs leads to metabolic disease. Reduction in abdominal fat stores reduces risks for metabolic diseases; hence, obesity diagnosis should be based on evidence from measuring excess abdominal fat and assessing its cardio-metabolic risk factors and symptoms (NASEM, 2024).

Evidence shows that the global prevalence of adult obesity rose from 12.1% in 2012 to 15.8% in 2022, while the global prevalence of anaemia in women of reproductive age (WRA) increased from 27.6% to 30.7% from 2012 to 2023 (FAO *et al*., 2025). Among the elderly, obesity prevalence increased from 13.1% in 2000 to 18.9% in 2022 (FAO *et al*., 2024). In Nigeria, overweight and obesity prevalence increased with advancing age as 13.2% and 5.2%, 19.6% and 12.1% and 23.8% and 15.5% being overweight and obese among those aged 20-29, 30-39 and 40-49 years, respectively. National values for overweight and obesity were 14.8% and 8.2%, respectively, while proportions for the South East were 21.2% and 15.5% and in rural areas of Nigeria, 12.8% and 5.2% were overweight and obese, respectively (FGoN and IITA, 2024).

Body Mass Index (BMI), a regular index for classifying weight status, does not assess health because in clinical settings, some patients with a BMI of greater than or equal to 30kg/m^2 are metabolically healthy while others with a normal BMI of less than or equal to 25kg/m^2 have excess abdominal fat and metabolic complications. Therefore, weight trajectory is a more accurate indicator, regardless of BMI, because BMI cannot distinguish type of fat or its complications (NASEM, 2024). The gold standard for measuring fat mass, lean mass and location is dual energy X-ray absorptiometry (DEXA), but it is not widely used because of radiation. Other tools such as bioelectrical impedance analysis (BIA), which is easy to use but often inaccurate and air displacement plethysmography, which measures body fat volume, but it is cumbersome, expensive and cannot specify fat location (NASEM, 2024). Despite its limitations, the present study used BIA to measure some body compositions.

Most importantly, high prevalence of food insecurity has been reported among Nigerian households and in rural areas as well. Despite the fact that the majority of Nigerians engage in one form of agriculture or the other, particularly in rural areas, food insecurity, low dietary diversity and nutrient adequacy still persist. There is a need for localised studies on those areas in order to get more evidence-based data, so that interventions will be directed to areas and population groups most in need. Agriculture contributes greatly to the national economy of the country, and the farmers are important stakeholders in that. Therefore, to ensure that the general population is adequately nourished and to reduce or eliminate food insecurity, the nutrition and health of the farmers is very important. To the authors' knowledge, few studies have used BIA to study such a large population in Nigeria. Therefore, in addition to revealing the BMI, fat, muscle and visceral fat compositions of the farmers, detailed relationships were unveiled. The relationships/ associations analysed are the major focus of this article; hence, the findings will add to the body of knowledge on associations/relationships between those variables on nutrition and health outcomes.

MATERIALS AND METHODS

Study area and population

The study was carried out in Bende, Oguta, Ngor Okpala and Ikwo Local Government Areas of Abia, Imo and Ebonyi States, respectively, all in the South East geopolitical zone of Nigeria. Bende is one of the seventeen Local Government Area of Abia State. Bende is one out of the three agricultural backbone of Abia State. The people of Bende are predominantly farmers and local traders. Oguta Local Government Area is one of the Local Government Areas in Imo State. Ngor Okpala Local Government Area is the largest Local Government Area in Imo State and one of the largest in Nigeria. Ikwo is the largest Local Government Area in Ebonyi State. It is situated in the eastern part of the State. The sample population of the study comprised adult men and women (non-pregnant or non-lactating) farmers who engage in farming at both commercial and subsistence levels.

Sample size

The sample size was determined using the percentage of farmers in Nigeria, which is 70% (FAO, 2022). This was calculated using the formula: $N = \frac{Z^2 \times P\ (100-P)}{X^2}$ (Winn *et al.,* 2006). Where N = sample size; Z = confidence interval, which is represented as 1.96; P = percentage of farmers in Nigeria, which is 70%; 100 – P = Percentage of persons assumed not to be farmers in Nigeria; and X = Width of confidence interval or required precision level taken to be 5%.

$$\mathrm{N} = \frac{1.96^2 \times 70\ (100-70)}{5^2}$$

$$\mathrm{N} = \frac{3.8416 \times 70(30)}{25}$$

$$\mathrm{N} = \frac{3.8416 \times 2100}{25}$$

$$\mathrm{N} = \frac{8067.36}{25}$$

N = 322.56

323 (approximately)

10% of 323 added to make up for attrition.

$$\frac{10}{100} \times \frac{323}{1}$$

= 0.1×323 = 32.3

Substituting the values in the equation gave a total of 323 plus 10% dropout, summing to 355 farmers chosen from each of the four Local Government Areas, with an overall sample size of 1420. However, 1342 farmers consented to the study and were interviewed.

Sampling procedure

Three states were randomly selected from the five Southeastern States in Nigeria. Thereafter, three Local Government Areas were purposively chosen from the randomly selected States because they are among the agricultural zones in the three states. The remaining one Local Government Area was randomly chosen from the already chosen state, which has the largest number of Local Government Areas.

Selection of farmers

A total list of all the registered farmers in the selected LGAs was obtained from the agricultural extension agents in the respective areas. A systematic sampling method was used in selecting the farmers recruited for the study. Random numbers were used to pick out a number to start with. Thereafter, the selected farmers were traced to their homes and were interviewed at a time and place convenient for them.

Strengths and limitations of the study

The use of farmers of different sex and age categories allows for comparison across sex, as well as the relatively large sample size. One of the potential setbacks of the study was the cross-sectional nature of the study, which makes it impossible to ascertain causal effects with respect to relationships noted.

Statistical analysis

The data from the questionnaire were entered into Microsoft Excel and coded. Thereafter, IBM SPSS Statistics for windows version 25.0 software programme was used for the analysis. Descriptive statistics of frequencies and percentages were used to present information on socio-demographic characteristics of the farmers. Pearson correlations between food security status, dietary diversity and nutrient adequacy were carried out. All relationships were judged significant at $P \leq 0.05$.

Ethics approval

Ethics approval was obtained from the Health Research Ethics Committee of the Federal Medical Centre Umuahia. The Research was approved on 27th February, 2024. The ethics assigned number is FMC/QEH/G.596/Vol.101728. Written and oral informed consents were obtained from literate and non-literate farmers, respectively before the interview.

RESULTS

The socio-demographic characteristics of the farmers are presented in Table 1. From the Table, there were more male (51.4%) than female (48.6%) farmers. The age range of the farmers showed that 35.3% were 46 years and above. The marital status showed that 65.7% were married and 26.4% were single. Education status showed that 59.6% completed secondary education, 18.9% primary, and 15.8% tertiary. Farming constituted the major occupation for 39.9%, but in addition to farming at a small scale, the other occupation reported was business (31.7%). The average monthly income indicated that 50.5% earned below N30000, and this was predominant in females (62.4%) than in males (39.3%).

A Pearson correlation coefficient was computed to determine the linear relationship between food insecurity experience scale scores, dietary diversity scores, mean adequacy ratio and body composition. The result is presented in Table 2. The result indicated that only body water showed a weak but significant negative relationship (r=-0.26, p=0.000) with FIESS. There was a strong positive significant (r=0.57, p=0.000) relationship between weight and BMI, while it was weak, positive and significant (r=0.29, p=0.000) between weight and body fat. There was a moderate positive significant (r=0.42, p=0.000) relationship between weight and visceral fat, as well as weight and body water, with r and p values of 0.36 and 0.000, respectively. Weight and RMC exhibited a strong positive significant relationship (r=0.50, p=0.000). A weak negative significant relationship (r=0.14, p=0.000) was noted between weight and BMM.

The relationship between height and BMI was weak, negative and non-significant (r=-.03, p=.330). At the 0.01 level of significance, BMI and body fat showed a strong positive significant (r=.70, p=.000) relationship. A similar strong positive significant (r=0.70, p=0.000) relationship was noted between BMI and visceral fat. The positive significant (r=0.27, p=0.000) relationship between BMI and body water was weak. However, a moderate positive significant (r=0.47, p=0.000) relationship existed between BMI and RMC. There was also moderate negative significant (r=-0.48, p=0.000) relationship between BMI and BMM,

The relationship between body fat and visceral fat was moderate, positive and significant (r=0.48, p=0.000), while a strong negative and significant (r=-0.80, p=0.000) relationship existed between body fat and BMM. A similar strong negative significant (r=-0.11, p=0.000) relationship was noted between body fat and body water. Body fat and RMC exhibited a weak negative significant (r=-0.07, p=0.011) relationship. Visceral fat and BMM showed a moderate negative significant (r=-0.33, p=0.000) relationship, while that between visceral fat and body water was weak, positive and significant (r=.19, p=.000) and that between visceral fat and RMC was moderate, positive and significant (r=0.43, p=0.000). There were weak positive significant (r=.28, p=.000) relationships between BMM and body water and between BMM and RMC (r=0.23, p=0.000). The relationship between body water and RMC was strong, positive and significant (r=0.61, p=0.000). The relationships between RMC and BMI, RMC and visceral fat were moderate, positive and significant with r and p values of 0.47, 0.000 and 0.43, 0.000, respectively.

In the Table, the relationship between DDS and BMM was weak positive significant (r=0.06, p=0.036). Also,

Table 1. Socio-demographic characteristics of the farmers

Variables	Male		Female		Total	
	F	%	F	%	F	%
Sex	690	51.4	652	48.6	1342	100.0
Age range (years)						
18-25	107	15.5	90	13.8	197	14.7
26-35	178	25.7	165	25.3	342	25.5
36-45	173	25.1	155	23.8	329	24.5
46 and above	232	33.1	242	37.1	474	35.3
Total	690	100.0	652	100.0	1342	100.0
Religion						
Christianity	645	93.6	641	98.3	1286	95.1
Islam	12	1.6	5	0.8	16	1.2
Traditional	33	4.8	6	0.9	39	3.7
Total	690	100.0	652	100.0	1342	100.0
Marital status						
Divorced	6	0.9	9	1.4	15	1.1
Married	443	64.3	438	67.2	882	65.7
Separated	4	0.6	4	0.6	8	0.6
Single	226	32.8	128	19.6	354	26.4
Widowed	11	1.5	73	11.2	83	6.2
Total	690	100.0	652	100.0	1342	100.0
Education status						
None	26	3.8	51	7.8	77	5.7
Primary	124	18.0	129	19.8	253	18.9
Secondary	428	62.0	372	57.1	800	59.6
Tertiary	112	16.3	100	15.3	212	15.8
Total	690	100.0	652	100.0	1342	100.0
Main Occupation						
Artisan	115	16.7	109	16.7	224	16.7
Businessman/woman	233	33.8	191	29.3	425	31.7
Civil/public servant	79	11.3	48	7.9	126	9.4
Farmer	248	36.0	288	44.2	536	39.9
Not employed	15	2.2	16	2.5	31	2.3
Total	690	100.0	652	100.0	1342	100.0
Income						
Less than ₦30000	271	39.3	407	62.4	678	50.5
₦ 30000 – 39000	226	32.7	158	24.2	384	28.6
₦ 40000 and above	193	28.0	87	13.3	280	20.9
Total	690	100.0	652	100.0	1342	100.0

MAR exhibited a strong positive significant (r=0.12, p=0.000) relationship with body water. There was a weak positive significant (r=0.08, p=.005) relationship between MAR and BMM.

Table 2. Relationship between food insecurity experience scale scores, dietary diversity scores, mean adequacy ratio and body compositions.

	FIESS	DDS	MAR	W (Kg)	H(m)	BMI (Kg/m^2)	BF (%)	VF (%)	BMM (%)	BW (litres)	RMC (Kcal)
FIESS	1			0.012 0.671	-0.011 0.687	0.002 0.928	0.004 0.884	0.037 0.173	-0.044 0.104	-0.258 0.000	-0.016 0.569
DDS	1	1		0.040 0.145	0.035 0.200	0.010 0.720	-0.013 0.642	0.024 0.373	0.057 0.036	0.002 0.933	0.042 0.121
MAR	1		1	0.022 0.423	0.021 0.447	-0.034 0.213	-0.039 0.156	-0.047 0.085	0.076 0.005	0.117 0.000	0.006 0.815
W(Kg)	0.012 0.671	0.040	0.022 0.423	1	0.001 0.962	0.571 0.000	0.287 0.000	0.417 0.000	-0.137 0.000	0.357 0.000	0.504 0.000
H (m)	-0.011 0.687	0.035 0.200	0.021 0.447	0.001 0.962	1	-0.027 0.330	-0.036 0.183	-0.017 0.531	0.045 0.103	0.034 0.217	0.034 0.208
BMI (Kg/m^2)	0.002 0.928	0.010 0.720	-0.034 0.213	0.571** 0.000	-0.027 0.330	1	0.703** 0.000	0.697 0.000	-0.481 0.000	0.272** 0.000	0.472 0.000
BF (%)	0.004 0.884	-0.013 0.642	-0.039 0.156	0.287** 0.000	0.036 0.183	0.703 0.000	1**	0.475 0.000	-0.800 0.000	-0.112** 0.000	-0.069 0.011
VF (%)	0.037 -	0.024 0.373	-0.047 0.085	0.417** -	-0.017 -	0.697 0.000	0.475** 0.000	1	-0.334 0.000	0.186** 0.000	0.430 0.000
BMM (%)	-0.044 0.104	0.057* 0.036	0.076** 0.005	-0.137** 0.000	0.045 0.103	-0.481 0.000	-0.800** 0.000	-0.334 0.000	1	0.283** 0.000	0.229 0.000
BW (Litres)	-0.258** 0.000	0.002 0.933	0.117** 0.000	0.357** 0.000	0.034 0.217	0.272** 0.000	-0.112** 0.000	0.186 0.000	0.283** 0.000	1**	0.606 0.000
RMC (Kcal)	0.569 -	0.042 0.121	0.006 0.815	0.000 -	0.208 -	0.472 0.000	-0.069** 0.011	0.430 0.000	0.229 0.000	0.606** 0.000	1

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed); **Key:** FIESS= Food insecurity experience scale scores; DSS= Dietary diversity scores; MAR= Mean adequacy ratios; W= weight; H= height; BMI= body mass index; BF= body fat; VF= visceral fat; BMM= body muscle mass; BW= body water and RMC= resting metabolic calorie.

DISCUSSION

The weak negative significant relationship between food insecurity experience scale scores (FIESS) and body water implied that as FIESS increases, body water decreases and vice versa. This could be due to the fact that food insecure persons often reduce their dietary quality as a means to cope with worsening food insecurity. This often arises from moderate to severe food insecurity, which are often of acute nature and persists for a short time due to shocks such as flooding, drought and conflicts. Leung *et al*. (2022) supported the assertion that food-insecure persons may have decreased total body water, probably due to consumption of less nutrient-dense foods such as refined carbohydrates and sugar-sweetened beverages plus other ultra-processed foods and beverages. Additionally, among United States adults, food insecurity was negatively associated with dietary quality, particularly intake of nutrient-rich vegetables, fruit and dairy (Hanson and Connor, 2014). A similar result, which was consistent with the present study was reported in urban Soweto, South Africa, where food-insecure women or those at risk of food insecurity consumed less diverse diets (Kehoe *et al*., 2021). However, the authors found that food security was not associated with weight and mid-upper-arm circumference. There were also no association between food insecurity and body mass index (BMI), fat mass index when adjusted for age, parity, education status and socio-economic status (Kehoe *et al*., 2021).

Food insecurity is a potential risk factor for malnutrition (Carvajal-Aldaz *et al*., 2022; Brandt *et al*., 2023). It has also been associated with obesity in many countries. For instance, in the Netherlands (van der Velde et al., 2020), Mexico (Ponce-Alcala et al., 2021), Iran (Hamedi-Shahraki et al., 2021), Brazil (Domingo et al., 2022; Laurentino et al., 2024), the United States (Rezaei et al., 2024), and Ethiopia (Yosef *et al*., 2024). All these reports contrasted the findings of the present study on no significant weak positive relationships between FIESS and weight, BMI, total body fat and visceral fat. The present study findings implied that worsening food security status did not result in an increase in weight, BMI, total body fat and visceral fat. In contrast to the findings, Laurentino *et al*. (2025) reported that BMI exhibited positive associations with all categories of food insecurity among Brazil cohort. In the late years of follow-up, among the adults, a positive association was noted between waist circumference and mild plus severe food insecurity. All the adults who were food insecure had their predicted means for weight and BMI progressively increased over time as the food insecurity became worse. The likely explanation for the lack of relationship reported for the present study may be because of the study population and their major occupation. The population studied was farmers whose majority were identified to operate at a subsistence level, with old implements. Most of the time, the farming activities were carried out by the majority of them. The intense physical activity associated with clearing, ploughing, planting, weeding, harvesting and others may have contributed to energy balance (input and output) and sometimes negative energy balance that could lead to underweight instead of weight gain. Also, the data were collected during the farming season characterised by busy farming activities. Location and design of the study also might have contributed to the observed differences in associations and relationships. It may also be true that nutrient-dense foods such as fruit and vegetables were available and often accessible to the farmers studied.

Furthermore, other variables (height, body muscle mass (BMM) and resting metabolic calorie (RMC) that showed negative non-significant weak relationship with FIESS implied that no noticeable impact was exerted by food insecurity on them. A moderately significant positive relationship was noted between weight and visceral fat, implying that an increase in weight led to a corresponding increase in visceral fat. A similar association was reported between visceral obesity and overweight/ elevated waist circumference among adults in Brazil (Chagas *et al*., 2025). However, after adjusting for confounders, the authors found that only physical inactivity and elevated waist circumference were associated with visceral fat accumulation. Also, waist circumference was an independent predictor of both visceral fat and subcutaneous adipose tissue. Nevertheless, other multiple factors such as genetics, sex, race, age, dietary habits, physical activity level, comorbidities and hormonal factors act synergistically to influence abdominal fat distribution (Lumish *et al*., 2020; Abe *et al*., 2022; Alsayed *et al*., 2024). The study by Winters-van Eekelen *et al*. (2021) was also consistent with that of the present study. Improved physical activity and reduced sedentary behaviour favour negative energy balance by increasing resting energy expenditure. Evidence suggests that visceral adipocytes are more sensitive to catecholamine stimulation released during exercise than subcutaneous adipocytes, and this leads to greater lipolytic capacity and removal of visceral fat accumulation (Ando *et al*., 2020; Abe *et al*., 2022).

In the present study, BMI and body fat exhibited strong positive significant relationship. This means that as the BMI of the farmers increase, their total body fat also increases. This was also applicable to BMI and visceral fat. An increase in BMI denoted positive energy balance, which overtime exceeded normal cut off value, tilting towards overweight and obesity. That suggested that energy input exceeded output and, as it persisted, led to excessive weight gain and abnormal total body fat and visceral fat percentages. Consistent with the result of this study, Laurentino *et al*. (2025) reported an increase in the prevalence of high BMI and abdominal obesity. An inverse association between lean muscle/ visceral fat mass and cardio-metabolic disorders such as dyslipidemia, hypertension and diabetes was reported. However, there was significant variation in the association between lean muscle/visceral fat and BMI and physical activity levels (Shao *et al*., 2025). Participants with moderate to vigorous physical activity levels showed a more pronounced association compared to less active individuals. Similarly, Ramirez-Valez *et al*. (2019) highlighted the protective role of the muscle mass-to-visceral fat ratio against metabolic syndrome. However, among individuals who are obese, the association weakened, which indicated the compounded metabolic burden imposed by excessive adiposity. The findings suggest that the balance between lean and visceral fat offered greater protective effects against dyslipidemia in younger and more physically active individuals, probably due to their greater metabolic resilience and preserved muscle mass (Shao *et al*., 2025).

The present study reported moderate negative significant relationship between BMI and body muscle mass. This implied that as their BMI decreases, BMM increases and vice versa. Similar to the findings, a United States cohort study of 38000 men showed a U-shaped correlation between lean mass and mortality, but fat mass exhibited a monotonic positive association with mortality (Lee *et al*., 2018). Generally, adipose or fat tissue is considered a metabolic load due to its link to insulin resistance, oxidative stress and endothelial dysfunction, particularly as fat mass increases. But muscle tissue in the form of muscle mass enhances metabolic capacity and is linked to positive metabolic outcomes such as glucose stabilisation, energy expenditure and aerobic capacity (Bosy-Westphal *et al*., 2018). The measurement and relation of BMI with visceral fat or central obesity enhances the validity of BMI in assessment of obesity, particularly in individuals with cardiovascular risk (Rao *et al*., 2015). Adiposity includes subcutaneous and visceral fat. However, excessive visceral fat accumulation is more associated with metabolic syndrome (Huang *et al*., 2023).

Dietary diversity scores (DDS) showed weak positive non-significant relationships with weight, height, BMI, visceral fat, BMM, total body water and RMC. This implies that dietary diversity of the farmers exerted neither noticeable positive or negative effects on those measures of body composition. Similarly, no statistically significant relationship between DDS and measures of body size or composition (weight, BMI, MUAC, waist circumference, fat mass, lean mass) was reported (Kehoe *et al*., 2021). However, Dello Russo *et al*. (2023) reported inconsistent results with the present study, as they found a statistically significant relationship between the odds ratio of overweight/obesity and DDS among adults in Europe. But after further adjustment for energy intake, no statistically significant association was noted. This suggests that high diverse diets could likely include nutrient-dense foods in contrast with low diverse diets, which may comprise mainly energy-dense foods. That could likely be the reason why no significant association was observed. Additionally, dietary diversity scores of the farmers revealed that most of their diets were diverse. Similarly, among their sampled population, a positive association was found between DDS and improved diet quality and across all age groups, the highest DDS textile showed statistically significantly higher fibre, fruit and vegetables and lower ultra-processed foods intakes (Dello Russo *et al*., 2023). Previous research among adults was also consistent with the findings that higher DDS was associated with higher meal frequency among pregnant women in Ethiopia and Madura (Yeneabat *et al*., 2019; Diana *et al*., 2020). Also, in line with the present study, no association was noted between DDS and adiposity and BMI because 5 out of the 16 cross-sectional studies in Europe analysed by Salehi-Abargouei *et al*. (2016) and Vadiveloo *et al*. (2013) reported inverse associations, while 7 showed no significant correlations. Generally, for the present study and the others cited, the no statistically significant relationship between DDS and adiposity/BMI in particular suggests that higher dietary diversity is linked with healthier diets or frequent consumption of nutrient-dense foods such as fruit and vegetables. Thus, variety within selected food groups might have a significant effect on nutrition outcomes and health.

Mean adequacy ratio (MAR), an indicator used to evaluate the nutrient intakes of the farmers, quantified their overall nutritional adequacy based on each farmer's diets as compared with the recommended nutrient intakes of each farmer according to sex and age. The MAR was used as a summary indicator of adequacy across twenty nutrients estimated for each of the farmers (Akter *et al*., 2021). The MAR is based on the nutrient adequacy ratio (NAR), a measure that expresses an individual's intake of a nutrient as a percentage (capped at 100%) of the corresponding recommended nutrient intake, given the person's age and sex. The MAR is then calculated by averaging the NAR (Data 4 Diets, 2023). In this study, MAR exhibited a weak positive non-significant relationship with weight, height and RMC, while it showed a weak negative non-significant relationship with BMI, body fat and visceral fat. In either case, no noticeable effect was exerted by MAR on those body compositions. However, MAR showed a strong positive relationship with total body water. That implied that as nutrient adequacy of the farmers increases, their total body water increases. Increased percentage total body water for each farmer suggests less percentage body fat and more percentage body muscle. Thus, it revealed the diet quality of the farmers. Consumption of nutrient-dense foods results in diverse and adequate diets, which may likely meet daily nutrient requirements, particularly vitamins and minerals. Fruit and vegetables are among the nutrient-dense foods, and they are good sources of water, hence the reason why MAR showed a strong positive relationship in this study. The study results showed that a good proportion of the farmers' nutrient intakes were adequate, although some were inadequate. Consistent with the results, previous and recent studies had demonstrated positive associations between diverse diets and nutrient adequacy in Belgium and among pregnant women in China (Vandevijvere *et al*., 2010; Zhong *et al*., 2022).

A weak positive significant relationship was noted between MAR and BMM. Although the relationship was not strong, it revealed the impact of adequate nutrition on body muscle mass, which improved as the MAR of the farmers increased. Achievement of a minimum dietary diversity score of greater than or equal to 5 food groups consisting at least 1 vegetable, 1 fruit, 1 pulse, nut or seeds, 1 animal source food, and 1 starchy staple constitutes an adequate diet (Global Diet Quality Project (GDQP), 2022). Diets prepared from these five food groups consistently over time will help build muscle, repair worn-out tissues and maintain new ones. Such diets will be generally varied, moderate, balanced, and diverse, all features of healthy diets. Such diets, in addition to supplying sufficient calories, are also nutrient-dense. The weak relationship noted between MAR and BMM may be because other factors aside from nutrition, such as age, sex, hormones, and exercise, contribute to muscle building. Age is a notable determinant because muscle mass declines with advancing age. It is not surprising then to notice such an effect because some of the farmers studied were older persons. Additionally, sex plays a crucial role as females tend to have more body fat and less muscle mass than males. The mix of both male and female farmers is an important variable that could likely have contributed to the weak relationship.

Conclusion

The study revealed that food insecurity decreased the quality and quantity of diets. However, it was not linked to weight, BMI, and central obesity, but a decrease in BMI increased muscle mass. In contrast, an increase in BMI led to corresponding increases in body fat, visceral or abdominal fat. Generally, the study revealed that body composition is affected by dietary intake either positively or negatively. Food insecurity can lead to poor-quality diets as well as diets deficient in energy as well. The resultant effect, as seen in the relationships, is malnutrition, which can manifest as imbalances in weight status. Dietary diversities of the farmers exerted no noticeable negative or positive effect on their body compositions. Similarly, mean adequacy ratios of the farmers were not related to their body compositions except total body water. In conclusion, nutrient-dense foods, when consumed consistently, will improve nutrient intakes because they are good sources of macro and micro nutrients.

Findings from this study have several implications for government policies and their implementation as they concern farmers in Nigeria and the general populace. In addition to programmes designed towards agricultural development, interventions aimed at the consumption of healthy, affordable and safe foods should be implemented, particularly for the farming population. This can be through content-specific nutrition education aimed at promoting proper food selection and preparation. There should be more collaboration between key stakeholders to identify dietary gaps and ensure improved intake of fruit and vegetables and moderate intake of animal source foods. Special policies and actions are designed to encourage high-quality staple foods by increasing nutrient density through interventions such as bio-fortification and fortification of staples and other major food products sold in the market, and strengthening of such programmes for greater coverage and impacts, particularly among rural farmers. This will improve their livelihood and income-generating capacity and ultimately improve nutrition and health.

CONFLICT OF INTEREST

There was no conflict of interest between the authors.

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