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Assessment of Subnutritional Indices and Associated Risk Factors of Malnutrition Among Older Adults

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Abstract

Malnutrition is a multifactorial problem affecting older adults especially in developing countries like Nigeria. Eighty-five subjects which comprise 55 older adults and 30 controls were recruited. Total protein, Albumin, Calcium, Vitamin-C and Vitamin D were estimated using Biuret's method, Bromo-Cresol Green method, O-Cresolphthalein-Complexone, High performance liquid chromatography, and ELISA methods respectively. Cognitive and nutritional status information were obtained using Mini-Cog test and MNA-short form. Data were analyzed at $p < .05$. Activities of daily living (ADL) was observed to be associated with nutritional status in older adults. The prevalence of older adults at risk of malnutrition was found to be 58.2%. Blood pressure, albumin and total protein were significantly higher in older adults ($p < .05$) compared to the younger adults. Total protein was significantly higher in older female subjects ($p < .05$) compared to older male subjects. It was also significantly higher in non- institutionalized older adults than in those who were institutionalized. Calf circumference was significantly lower ($p < .05$) in those with poor cognitive status. BMI and calcium were significantly lower in the malnourished older adults. It is concluded that older adults who are dependent, most of which are institutionalized may be more exposed to malnutrition, frailty and cognitive impairment.

Keywords

older adults, nutritional indices, malnutrition, frailty, cognitive impairment

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Introduction

Malnutrition among older adults is a significant public health issue with profound implications for individuals and healthcare systems globally (Cate et al., 2020; Pirlich & Lochs, 2001). As the population ages, the prevalence of nutritional deficiencies increases, leading to a range of health complications, including reduced immunity, impaired wound healing, and increased morbidity and mortality (Milne et al., 2009; Serrano-Urrea & Garcia-Meseguer, 2013). Despite various interventions, malnutrition remains a persistent and under-recognized problem in this demographic. (Krishnamoorthy et al., 2018; Serrano-Urrea & Garcia-Meseguer, 2013).

In Europe and North America, malnutrition prevalence ranges from 1% to 15% among non-institutionalized older adults, 25% to 60% in geriatric care facilities, and 35% to 65% in hospitals (Figueroa-Méndez & Rivas- Arancibia, 2015; Omran & Morley, 2000). With the expected global increase in life expectancy, the population over 80 years is projected to rise significantly by 2050, increasing the risk of malnutrition (Figueroa-Méndez & Rivas- Arancibia, 2015; Krishnamoorthy et al., 2018). In Sub-Saharan Africa, up to 48% of the elderly population is underweight, while 56% of older

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South Africans are obese (Kimokoti & Hamer, 2008; Naidoo & Vanwyk, 2020). A cross-sectional study in Ibadan, Nigeria, revealed that 61.9% of adults aged 60 and above had nutritional issues, with 7.8% undernourished and 54.1% overweight (Adebusoye et al., 2012).

Malnutrition encompasses both undernutrition and overnutrition of macronutrients and micronutrients (Berner, 2003; Ritchie & McClave, 2002). Various factors, including dental issues, medications, reduced appetite, and environmental influences, increase the elderly's risk of malnutrition (Corcoran et al., 2019; Ritchie & McClave, 2002). A study in southern Ireland reported high dietary insufficiencies among older adults (O'Connell et al., 2021). Older adults frequently have low vitamin D levels due to inadequate dietary intake and reduced skin exposure to ultraviolet light, increasing the risk of sarcopenia and calcium malabsorption (Remelli et al., 2019). Studies in Asia have reported widespread prevalence of vitamin D deficiency and insufficiency in older adults (Nimitphong & Holick, 2013) with deficiency defined as serum vitamin D level $< 20\,\mu g/L$ and insufficiency defined as vitamin D level between 20–$<30\,\mu g/L$ (Holick, 2007). Vitamin D deficiency impairs calcium absorption, leading to osteoporosis, frailty, and reduced quality of life (Siddique et al., 2017). Frailty is often associated with micronutrient deficiencies, including vitamin C, which impacts iron absorption and prevents anemia and fatigue (Bjarnadottir, 2019; Sharma et al., 2021). Protein-energy malnutrition is prevalent in older adults and is linked to low muscle mass and physical frailty (Mathewson et al., 2021). Albumin levels, which decrease with age, serve as an indicator of malnutrition (Keller, 2019). Observational studies conducted with community-dwelling individuals, and institutionalized patients (including hospitals and long-term care institutions) highlighted a strong inverse correlation between the serum protein concentration and the risk of subsequent multimorbidity and mortality (Dennis, 2021). Understanding the specific subnutritional indices and the associated risk factors of malnutrition in older adults is crucial for developing targeted and effective interventions.

Methods

Study Design

This study was conducted in Calabar metropolis, Cross River State, Nigeria. The target population consisted of older adults aged 65 years and above in the Calabar metropolis. A total of 85 subjects were enrolled into the study, with 55 participants aged 65 years and above, and 30 controls (younger aged 20–40 years). A well-structured questionnaire, including the Mini Nutritional Assessment short form and Mini-Cog (cognitive) test was used to collect demographic information, as well as assess nutritional and cognitive status. The sample size was calculated using the formula for estimating proportions in a population (Dell et al., 2002):

$$N = \frac{z^2 * p\,(1 - p)}{d^2}$$

where:

- n is the sample size,
- Z is the Z-value (1.96 for a 95% confidence level),
- p is the estimated proportion of the population with the characteristic of interest, that is, 3.54% prevalence of malnutrition among older adults from previous studies (Seid & Babbel, 2022)
- d is the margin of error (0.05).

Using these values, the minimum required sample size was calculated to be 52. A stratified random sampling method was employed to select participants. The older adults were stratified based on their living conditions (institutionalized and non-institutionalized) to ensure diverse representation. Within each stratum, participants were randomly selected using a list of eligible individuals. Written informed consent was obtained from all subjects before recruitment into the study. The study was carried out in accordance with the ethical principles for research involving human subjects, as outlined in the Helsinki declaration in 1975 and subsequent revisions. Older adults that were extremely sick and/or having neurological conditions were excluded from this study.

Physical Examination

Systolic blood pressure and diastolic blood pressure were measured three times using a standard mercury sphygmomanometer by well-trained nurses. Weight and height of each subject were measured using a weighing balance and a calibrated measuring ruler respectively. The mid upper arm circumference (MUAC) was also measured using a measuring tape around the arm at the midpoint mark. The calf circumference was also measured using measuring tape round the calf of the subjects and read to the nearest centimeters (cm). Body mass index was derived as the ratio of the body mass (weight) in kilogram to the square of the body height (meters). It is expressed in units of kg/m^2. BMI = weight (kg)/height (m^2). Waist-hip ratio is the ratio of the circumference of the waist to that of the hip, calculated as waist measurement divided by hip measurement.

Sample Collection

Five (5) milliliters of blood was collected aseptically from each subject into plain bottles. It was then left to clot, and after which it was spun at 3,000 rpm for 5 min. The serum was extracted and transferred into a serum container, and frozen till when needed for analysis.

Materials/Laboratory Methods

Materials. High performance liquid chromatography-grade acetonitrile (99.9% volume/volume) from Merck (Darmstadt, Germany).

Human Vitamin D (VD) ELISA kit obtained from SunLong Biotech Co. LTD.

Albumin BromoCresol Green Method kit obtained from QuimicaClinicaAplicada S.A, Spain.

Total Protein Biuret Method obtained from Randox Laboratories Limited, United Kingdom.

Calcium O-CPC kit obtained from Randox Laboratories Ltd, United Kingdom.

Mini Nutritional Assessment- Short Form obtained from Nestle Nutrition Institute-Switzerland.

Mini Cog™ Assessment

Estimation of Vitamin C

Vitamin C was estimated using High performance liquid chromatography- grade acetonitrile.

Principle. The ascorbic acid is strongly influenced by oxygen to prevent oxidation. Dithiothreitol (DTT) was used. The FIA/HPLC-ED system consist of two solvent delivery pumps operating in the range 0.001 to 9.999 mL/min, a reaction coil and Metachem Polaris C18A reversal- phase column and a CoulArray electrochemical detector includes two flow cells, each cell consists of four analytical cells containing working carbon porous electrode, two auxiliary, and two reference electrodes.

Procedure. The sample (5 µL) was injected into the HPLC machine manually after the samples were diluted with acetonitrile water and filtered through 0.45 µL Teflon membrane filter. The recovery of Ascorbic acid was evaluated with spike of the standard and Ascorbic acid concentration was derived from the calibration curves.

Estimation of Vitamin D

This was carried out using the Sandwich-Enzyme Linked Immunosorbent Assay (ELISA).

Principle. This Microelisa strip plate provided in this kit has been pre-coated with an antibody specific to VD. Standards or samples added to the appropriate Microelisa strip plate wells and combined to the specific antibody. Then, a Horseradish Peroxidase (HRP)-conjugated antibody specific for VD is added to each Microelisa strip plate well and incubated. Free components are washed away. The TMB substrate solution is added to each well. Only those wells that contain VD and HRP conjugated VD antibody will appear blue in color and then turn yellow after the addition of the stop solution. The optical density (OD) is measured spectrophotometrically at a wavelength of 450 nm. The OD value is proportional to the concentration of VD in the samples by comparing the OD of the sample to the standard curve.

Procedure. Standards were diluted by small tubes first. Then, the volume of 50 µL was pipette from each tube to microplate well. In the microelisastripplate, for blank control, a well was left empty. In sample wells, 40 µL of sample dilution buffer and 10 µL of sample were added (dilution factor is 5). Sample was loaded onto the bottom without touching the well wall. It was mixed well with gentle shaking. It was then sealed with closure plate membrane and incubated for 30 min at 37°C. The concentrated washing buffer was diluted with distilled water. The closure plate membrane was peeled off and the wash solution aspirated and used to refill. The wash solution was discarded after resting for 30 s. Washing solution was repeated for 5 times. To each well (except the blank control well), add 50 µL of HRP-Conjugate reagent. Incubate for 30 min at 37°C. It was then washed as described earlier. Fifty microliters of chromogen solution A and 50 µL of Chromogen solution B were added across the wells. It was mixed, gently shaken and incubated at 37°C for 15 min. Lastly, 50 µL of the stop solution was added to each well to terminate the reaction. The color in the well changes from blue to yellow and absorbance is read 450 nm using a Microtiter plate reader.

Estimation of Albumin

This was estimated using BromoCresol Green method.

Principle. At acidic pH, albumin specifically combined with bromocresol green (BCG) to form a colored complex that is determined photometrically. The color produced in the reaction is proportional to the concentration of albumin in the sample under optimal assay conditions.

Procedures. Ten (10) microliters of the standard was added into a test tube. Ten microliters of the sample was added to another test tube. 2.5 mL of the reagent was added across. It was then mixed and incubated for 5 min at room temperature (20°C–25°C). Absorbance of the standard and sample was measured against reagent blank at 630 nm.

Estimation of Total Protein

Estimated using Biuret method.

Principle. Cupric ions, in an alkaline medium, interact with protein peptide bonds resulting in the formation of a colored complex.

Procedure. Ten (10) microliters of the standard was added into a test tube. Ten microliters of the sample was added to another test tube. Ten microliter of distilled

water was added to another test tube. About 1000 µL of the reagent was added across. It was then mixed and incubated for 30 min at 20°C to 25°C. Absorbance of the standard and sample was measured against reagent blank at 500 to 520 nm.

Estimation of Calcium

This was determined using O-Cresolphthalein complexone colorimetric method, without deproteinization.

Principle. Calcium ions react with O-cresolphthalein complexone (O-CPC) under alkaline conditions to form a violet-colored complex. The color intensity of the complex formed is directly proportional to the calcium concentration. It is determined by measuring the increase in absorbance at 570 nm.

Procedure. Ten (10) microliters of the standard was added into a test tube. Ten microliters of the sample was added to another test tube. 0.5 mL of reagent 1 (a buffer containing 2-Amino-2-methyl-1-propanol with pH of 10.5) was added across the tubes (blank, standard, sample tubes). After which, 0.5 mL of reagent 2 (a chromogen containing O-cresolphthalein complexone and 8-hydroxyquinoline) was added across. It was then mixed and incubated for 5 min at 20°C to 25°C. Absorbance of the standard and sample was measured against reagent blank at 578 nm.

Statistical Analysis

After results have been obtained, it was further analyzed on SPSS (statistical package for social sciences) software version 22.0. The data were presented as mean ± standard deviation. Students' *T*-test (to ascertain the difference(s) between two groups), ANOVA (to ascertain the difference(s) among groups), Chi-square (to check for an association between variables) and Pearson's correlation (to check for the relationship between variables) were used. The level of significance was set at $p < .05$.

Results

Table 1 shows the socio-demographic characteristics of older adults in Calabar metropolis, and the major population were those within the ages of 65 to 75 years of age (78.2%). The majority of respondents had acquired tertiary education (32.7%). A good percent of the respondents had no occupation (34.5%), others were either farmers (21.8%) or into businesses (16.4%). About 3.6% and 16.4% are pensioners or public servants respectively. Respondents were predominantly from the Efik tribe (38.2%). Majority of the respondents were married (38.2%), while 5.5% were widowers, 34.5% were widows and a few percent were single (14.5%) or divorced (7.3%). Regarding activities of daily living, 80% were independent, 14.55% required assistance, while 5.45% were dependent. Table 1 also shows the influence of socio-demographic characteristics of respondents on their nutritional status. There was a statistically significant influence ($\chi^2 = 15.968$, $p < .05$) of activities of daily living on nutritional status.

Table 2 shows the comparison of mean age, body mass index (BMI), calf circumference, mid arm circumference (MAC), waist hip ratio (WHR), systolic and diastolic pressure, mean Albumin (ALB), Total Protein (TP), Calcium, Vitamin C (Vit. C), and Vitamin D (Vit. D) in older adults and younger adults. Age, systolic and diastolic blood pressure, TP, and ALB were significantly higher ($p < .05$) in older adults compare to the younger adults.

Table 3 shows effect of gender on mean age, body mass index (BMI), calf circumference, mid upper arm circumference (MUAC), waist hip ratio (WHR), systolic and diastolic pressure, mean Albumin (ALB), Total Protein (TP), Calcium, Vitamin C (Vit. C), and Vitamin D (Vit. D) in older adults. Total Protein was significantly higher ($p < .05$) in the older female, compared with the male.

Table 4. Shows the mean age, body mass index (BMI), calf circumference, mid arm circumference (MAC), waist hip ratio (MAC), systolic and diastolic pressure, mean Albumin (ALB), Total Protein (TP), Calcium, Vitamin C (Vit. C), and Vitamin D (Vit. D) in Institutionalized and Non-Institutionalized older adults. Total Protein was significantly higher ($p < .05$) in the non-institutionalized subjects, compared with the institutionalized subjects.

Table 5. Shows the Variation of the measured parameters in older adults based on cognitive status, those with good cognitive status had mean age, body mass index (BMI), calf circumference, mid upper arm circumference (MUAC), waist hip ratio (WHR), systolic and diastolic pressure, mean Albumin (ALB), Total Protein (TP), Calcium, Vitamin C (Vit. C) and Vitamin D (Vit. D) of 68.71 ± 6.44 years, 25.25 ± 5.66 kg/m^2, 33.66 ± 3.75 cm, 29.24 ± 3.18 cm, 0.88 ± 0.08, 139.26 ± 20.15 mmHg, 84.16 ± 15.95 mmHg, 4.66 ± 0.74, 8.19 ± 3.81, 1.78 ± 0.52, 1.26 ± 1.35, and 75.47 ± 45.36 respectively, while those with fair cognitive status had 71.29 ± 6.84 years, 24.07 ± 4.41 kg/m^2, 32.44 ± 3.13 cm, 29.57 ± 4.01 cm, 0.88 ± 0.05, 143.43 ± 29.03 mmHg, 83.86 ± 8.08 mmHg, 4.93 ± 0.91, 9.17 ± 5.17, 1.83 ± 0.73, 1.44 ± 1.72, and 85.22 ± 29.54 respectively. Those with poor cognitive status had 69.70 ± 7.09 years, 22.17 ± 5.63 kg/m^2, 30.38 ± 4.46 cm, 26.40 ± 4.18 cm, 0.89 ± 0.05, 149.00 ± 37.67 mmHg, 84.00 ± 16.57 mmHg, 4.73 ± 0.71, 8.05 ± 3.76, 1.92 ± 0.64, 0.93 ± 1.70, and 76.84 ± 34.34 respectively, there was however no statistically significant ($p < .05$) variation across the groups.

Table 6. Shows the Variation of the measured parameters in older adults based on MNA-SF status, those with normal status had mean age, body mass index

Table 1. Influence of Socio-Demographic Characteristics of Respondents on Their Nutritional Status.

Variable	Number enrolled	Frequency	Nutritional status			*p*-Value	χ^2
			At risk (%)	Malnourished (%)	Normal (%)		
Age group							
65–75	43	78.2	25 (58.1)	4 (9.3)	14 (32.6)	.994	0.011
>75	12	21.8	7 (58.3)	1 (8.3)	4 (33.3)		
Gender							
Male	19	34.5	11 (57.9)	1 (5.3)	7 (36.8)	.734	0.618
Female	36	65.5	21 (58.3)	4 (11.1)	11 (30.6)		
Marital status							
Single	8	14.5	6 (75.0)	1 (12.5)	1 (12.5)	.812	4.472
Married	21	38.2	12 (57.1)	1 (4.8)	8 (38.1)		
Divorced	4	7.3	3 (75.0)	0 (0.0)	1 (25.0)		
Widow	19	34.5	9 (47.4)	3 (15.8)	7 (36.8)		
Widower	3	5.5	2 (66.7)	0 (0.0)	1 (33.3)		
Educational status						.429	5.951
Informal	14	25.5	10 (71.4)	1 (7.1)	3 (21.4)		
Primary	8	14.5	3 (37.5)	1 (12.5)	4 (50.0)		
Secondary	15	27.3	6 (40.0)	2 (13.3)	7 (46.7)		
Tertiary	18	32.7	13 (72.2)	1 (5.6)	4 (22.2)		
Income						.210	10.861
None	14	25.5	11 (78.6)	2(14.3)	1 (7.1)		
<5,000	2	3.6	1 (50.0)	0(0.0)	1 (50.0)		
5,000–20,000	14	25.5	4 (28.6)	2(14.3)	8 (57.1)		
20,000–50,000	8	14.5	5 (62.5)	0(0.0)	3 (37.5)		
Pensioner	17	30.9	11 (64.7)	1(5.9)	5 (29.4)		
Occupation						.310	11.642
None	19	34.5	12 (63.2)	2 (10.5)	5 (26.3)		
Business	9	16.4	4 (44.4)	1 (11.1)	4 (44.4)		
Farmer	12	21.8	5 (41.7)	1 (8.3)	6 (50.0)		
Pensioner	2	3.6	0 (0.0)	0 (0.0)	2 (100.0)		
Public servant	9	16.4	7 (77.8)	1 (11.1)	1 (11.1)		
Others	4	7.3	4 (100.0)	0 (0.0)	0 (0.0)		
Activities of daily living							
Dependent	3	5.5	1 (33.3)	2 (66.7)	0 (0.0)	.003	15.968
Independent	44	80.0	24 (54.5)	3 (6.8)	17 (38.6)		
Requires assistance	8	14.5	7 (87.5)	0 (0.0)	1 (12.5)		
Polypharmacy							
Yes	33	60.0	21 (63.6)	3 (9.1)	9 (27.3)	.557	1.172
No	22	40.0	11 (50.0)	2(9.1)	9 (40.9)		

Table 2. Comparison of the Study Demographic Data, ALB, TP, Ca, Vit. C, and Vit. D in Older Adults and Younger Adults.

Group/variables	Older adults $n = 55$	Younger adults $n = 30$	*t*	*p*-Value
AGE (years)	71.55 ± 6.62	31.37 ± 15.23	19.55	.000*
BMI (kg/m^2)	24.39 ± 5.39	23.61 ± 5.83	0.622	.536
Calf circumference (cm)	32.75 ± 3.88	33.79 ± 3.76	–1.195	.236
MUAC (cm)	28.81 ± 3.70	28.75 ± 3.42	0.0680	.946
WHR (inches)	0.88 ± 0.07	0.85 ± 0.14	1.274	.206
SYS (mmHg)	142.09 ± 26.05	114.60 ± 11.85	5.468	.000*
DIA (mmHg)	84.05 ± 14.24	74.07 ± 8.48	3.512	.001*
ALB (g/dL)	4.74 ± 0.77	4.30 ± 0.51	2.844	.006*
TP (g/dL)	8.42 ± 4.13	5.91 ± 0.64	3.289	.001*
Vit. C (mg/dL)	1.24 ± 1.49	0.67 ± 1.34	1.747	.084
Ca (mMol/L)	1.82 ± 0.59	1.92 ± 0.24	–0.912	.364
Vit. D (ng/mL)	78.20 ± 39.59	82.20 ± 33.05	–0.471	.639

Note. Values are expressed as mean ± standard deviation, where BMI = Body Mass Index; WHR = Waist Hip Ratio; MUAC = midupper arm circumference; SYS = systolic blood pressure; DIA = diastolic blood pressure; TP = total protein; ALB = albumin; Ca = calcium; Vit. C = vitamin C; Vit. D = vitamin D.
*Significant at $p < .05$.

Table 3. Effect of Gender on the Measured Parameters in Older Adults.

Group/variables	Male $n = 19$	Female $n = 36$	t	p-Value
BMI (kg/m^2)	24.11 ± 4.47	24.54 ± 5.88	–0.280	.780
Calf circumference (cm)	33.24 ± 3.73	32.50 ± 4.00	0.669	.506
MUAC (cm)	28.59 ± 3.29	28.92 ± 3.94	–0.304	.762
WHR (inches)	0.89 ± 0.04	0.88 ± 0.08	0.301	.765
SYS (mmHg)	139.47 ± 25.70	143.47 ± 26.49	–0.538	.593
DIA (mmHg)	83.63 ± 18.78	84.28 ± 11.46	–0.159	.875
ALB (g/dL)	4.61 ± 0.64	4.82 ± 0.84	–0.950	.346
TP (g/dL)	6.95 ± 0.99	9.19 ± 4.90	–1.956	.056*
Vit. C (mg/dL)	1.47 ± 1.33	1.13 ± 1.57	0.807	.423
Ca (mMol/L)	1.87 ± 0.47	1.79 ± 0.65	0.446	.658
Vit. D (ng/mL)	73.35 ± 21.97	80.76 ± 46.37	–0.657	.514

Note. Values are expressed as mean ± standard deviation, where BMI = Body Mass Index; WHR = waist hip ratio; MUAC = midupper arm circumference; SYS = systolic blood pressure; DIA = diastolic blood pressure; TP = total protein; ALB = albumin; Ca = calcium; Vit. C = vitamin C; Vit. D = vitamin D.
*Significant at $p < .05$.

Table 4. Comparison of Measured Parameters in Institutionalized and Non-Institutionalized Subjects.

Group/variables	INST. $n = 14$	NON-INST $n = 41$	t	p-Value
BMI (kg/m^2)	25.64 ± 5.96	23.96 ± 5.20	1.008	.318
Calf circumference (cm)	33.64 ± 4.91	32.45 ± 3.48	0.995	.324
MUAC (cm)	29.64 ± 4.52	28.52 ± 3.40	0.979	.332
WHR (inches)	0.87 ± 0.04	0.88 ± 0.08	–0.502	.618
SYS (mmHg)	146.93 ± 23.93	140.44 ± 26.82	0.802	.426
DIA (mmHg)	83.36 ± 13.37	84.29 ± 14.68	–0.210	.834
ALB (g/dL)	4.91 ± 0.28	4.69 ± 0.88	0.900	.372
TP (g/dL)	6.34 ± 0.24	9.13 ± 4.58	–2.264	.028*
Vit. C (mg/dL)	1.23 ± 1.63	1.25 ± 1.46	–0.050	.961
Ca (mMol/L)	1.80 ± 0.31	1.82 ± 0.66	–0.106	.916
Vit. D (ng/mL)	70.25 ± 31.30	80.92 ± 42.04	–0.869	.389

Note. Values are expressed as mean ± standard deviation, where BMI = Body Mass Index; WHR = Waist Hip Ratio; MUAC = mid upper arm circumference; SYS = systolic blood pressure; DIA = diastolic blood pressure; TP = total protein; ALB = albumin; Ca = calcium; Vit. C = vitamin C; Vit. D = vitamin D.
*Significant at $p < .05$.

Table 5. Variation of the Measured Parameters in Older Adults Based on Cognitive Status Using the Mini Cog™.

Group/variables	Good $n = 31$	Fair $n = 14$	Poor $n = 10$	F-ratio	p-Value
BMI (kg/m^2)	25.25 ± 5.66	24.07 ± 4.41	22.17 ± 5.63	1.280	.287
Calf circumference (cm)	33.13 ± 5.89	31.38 ± 5.91	27.47 ± 6.82	3.424	.040*
MUAC (cm)	29.24 ± 3.18	29.57 ± 4.01	26.40 ± 4.18	2.791	.071
WHR (inches)	0.88 ± 0.08	0.88 ± 0.05	0.89 ± 0.05	0.074	.929
SYS (mmHg)	139.26 ± 20.15	143.43 ± 29.03	149.00 ± 37.67	0.544	.584
DIA (mmHg)	84.16 ± 15.95	83.86 ± 8.08	84.00 ± 16.57	0.002	.998
ALB (g/dL)	4.66 ± 0.74	4.93 ± 0.91	4.73 ± 0.71	0.558	.576
TP (g/dL)	8.19 ± 3.81	9.17 ± 5.17	8.05 ± 3.76	0.309	.735
Vit. C (mg/dL)	1.26 ± 1.35	1.44 ± 1.72	0.93 ± 1.70	0.341	.713
Ca (mMol/L)	1.78 ± 0.52	1.83 ± 0.73	1.92 ± 0.64	0.218	.805
Vit. D (ng/mL)	75.47 ± 45.36	85.22 ± 29.54	76.84 ± 34.34	0.292	.748

Note. Values are expressed as mean ± standard deviation, where BMI = Body Mass Index; WHR = waist hip ratio; MUAC = mid upper arm circumference; SYS = systolic blood pressure; DIA = diastolic blood pressure; TP = total protein; ALB = albumin; Ca = calcium; Vit. C = vitamin C; Vit. D = vitamin D.

Table 6. Variation of the Measured Parameters in Older Adults Based on Nutritional Status Using MNA-SF.

Group/variables	Normal $n = 18$	At risk $n = 32$	Malnourished $n = 5$	*F*-ratio	*p*-Value
BMI (kg/m^2)	26.38 ± 3.05	24.17 ± 6.15	18.63 ± 0.65	4.666	.014*
Calf circumference (cm)	32.38 ± 3.30	33.34 ± 4.14	30.30 ± 3.63	1.480	.237
MUAC (cm)	29.65 ± 3.48	28.57 ± 3.86	27.30 ± 3.38	0.946	.395
WHR (inches)	0.91 ± 0.05	0.86 ± 0.07	0.88 ± 0.07	2.934	.062
SYS (mmHg)	134.11 ± 17.06	148.34 ± 29.52	130.80 ± 20.29	2.347	.106
DIA (mmHg)	84.90 ± 13.25	84.34 ± 14.95	79.20 ± 15.06	0.320	.728
ALB (g/dL)	4.69 ± 0.79	4.79 ± 0.79	4.67 ± 0.75	0.108	.898
TP (g/dL)	8.16 ± 3.95	8.24 ± 4.04	10.50 ± 5.60	0.696	.503
Vit. C (mg/dL)	1.19 ± 1.34	1.33 ± 1.66	0.87 ± 0.95	0.219	.804
Ca (mMol/L)	2.01 ± 0.61	1.79 ± 0.56	1.27 ± 0.40	3.432	.040*
Vit. D (ng/mL)	73.76 ± 23.86	82.32 ± 47.95	67.81 ± 23.67	0.449	.641

Note. Values are expressed as mean ± standard deviation, where BMI = Body Mass Index; WHR = waist hip ratio; MUAC = mid upper arm circumference; SYS = systolic blood pressure; DIA = diastolic blood pressure; TP = total protein; ALB = albumin; Ca = calcium; Vit. C = vitamin C; Vit. D = vitamin D.
*Significant at $p < .05$.

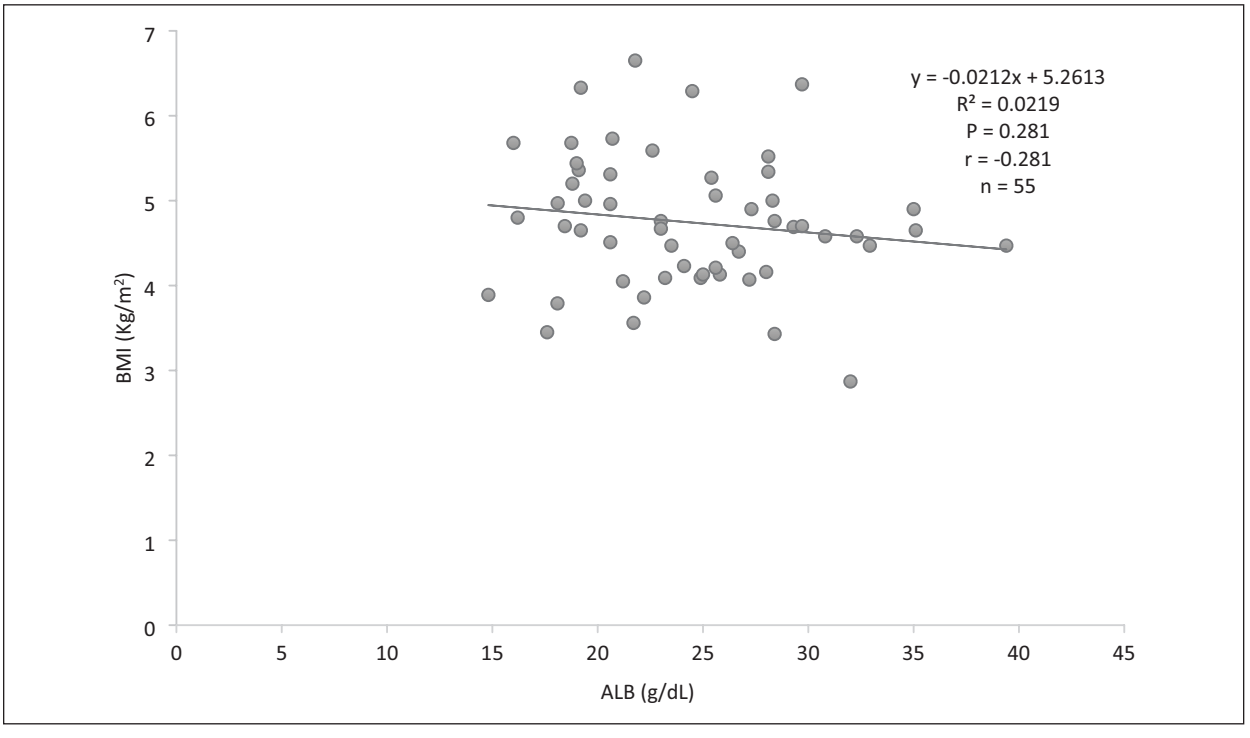

Figure 1. Correlation plot of BMI against ALB.

(BMI), calf circumference, mid arm circumference (MAC), waist hip ratio (MAC), systolic and diastolic pressure, mean Albumin (ALB), Total Protein (TP), Calcium, Vitamin C (Vit. C), and Vitamin D (Vit. D) of 69.56 ± 7.24 years, 26.38 ± 3.05 kg/m^2, 32.38 ± 3.30 cm, 29.65 ± 3.48 cm, 0.91 ± 0.05 inches, 134.11 ± 17.06 mmHg, 84.90 ± 13.25 mmHg, 4.69 ± 0.79 g/dL, 8.16 ± 3.95 g/dL, 2.01 ± 0.61 mmol/L, 1.19 ± 1.34 mg/dL, and 73.76 ± 23.86 ng/mL respectively, while those at risk had 68.91 ± 6.61 years, 24.17 ± 6.15 kg/m^2, 33.34 ± 4.14 cm, 28.57 ± 3.86 cm, 0.86 ± 0.07 inches, 148.34 ± 29.52 mmHg, 84.34 ± 14.95 mmHg, 4.79 ± 0.79 g/dL, 8.24 ± 4.04 g/dL, 1.79 ± 0.56 mmol/L, 1.33 ± 1.66 mg/dL and 82.32 ± 47.95 ng/mL respectively. Those who are malnourished had 73.60 ± 2.70 years, 18.63 ± 0.65 kg/m^2, 30.30 ± 3.63 cm, 27.30 ± 3.38 cm, 0.88 ± 0.07 inches, 130.80 ± 20.29 mmHg, 79.20 ± 15.06 mmHg, 4.67 ± 0.75 g/dL, 10.50 ± 5.60 g/dL, 1.27 ± 0.40 mmol/L, 0.87 ± 0.95 mg/dL, 67.81 ± 23.67 ng/mL respectively, there was statistically significant ($p < .05$) in Calcium and BMI across the groups.

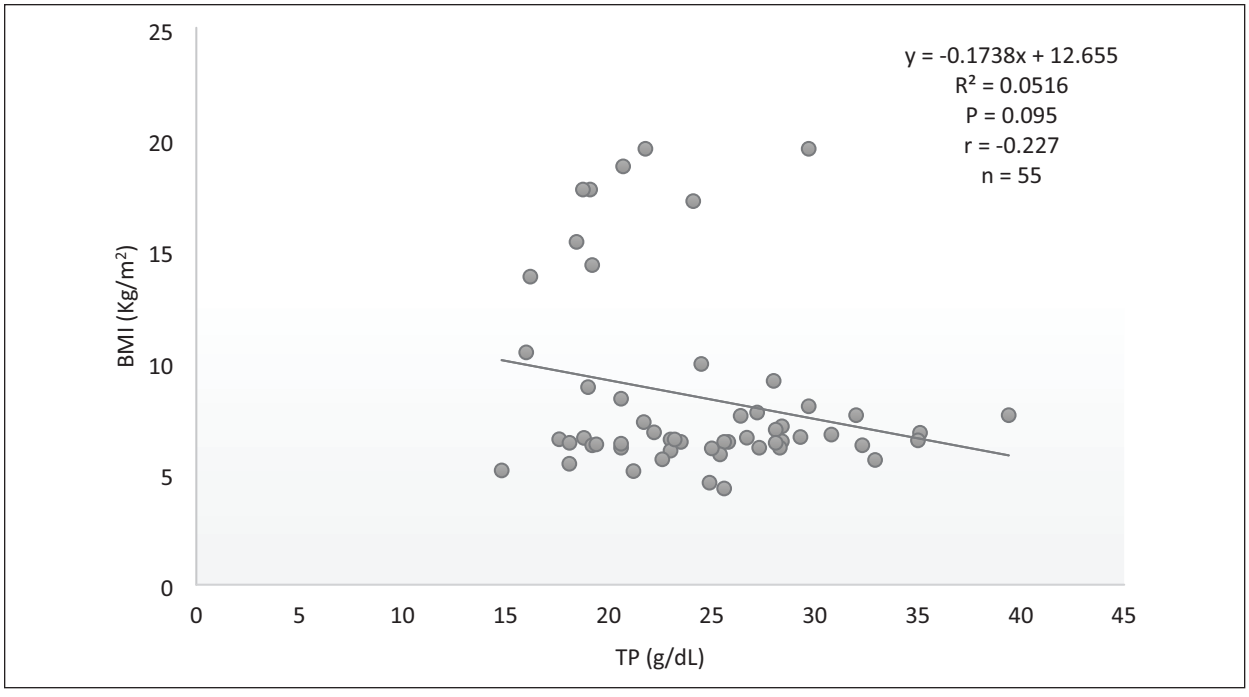

Figure 2. Correlation plot of BMI against total protein (TP).

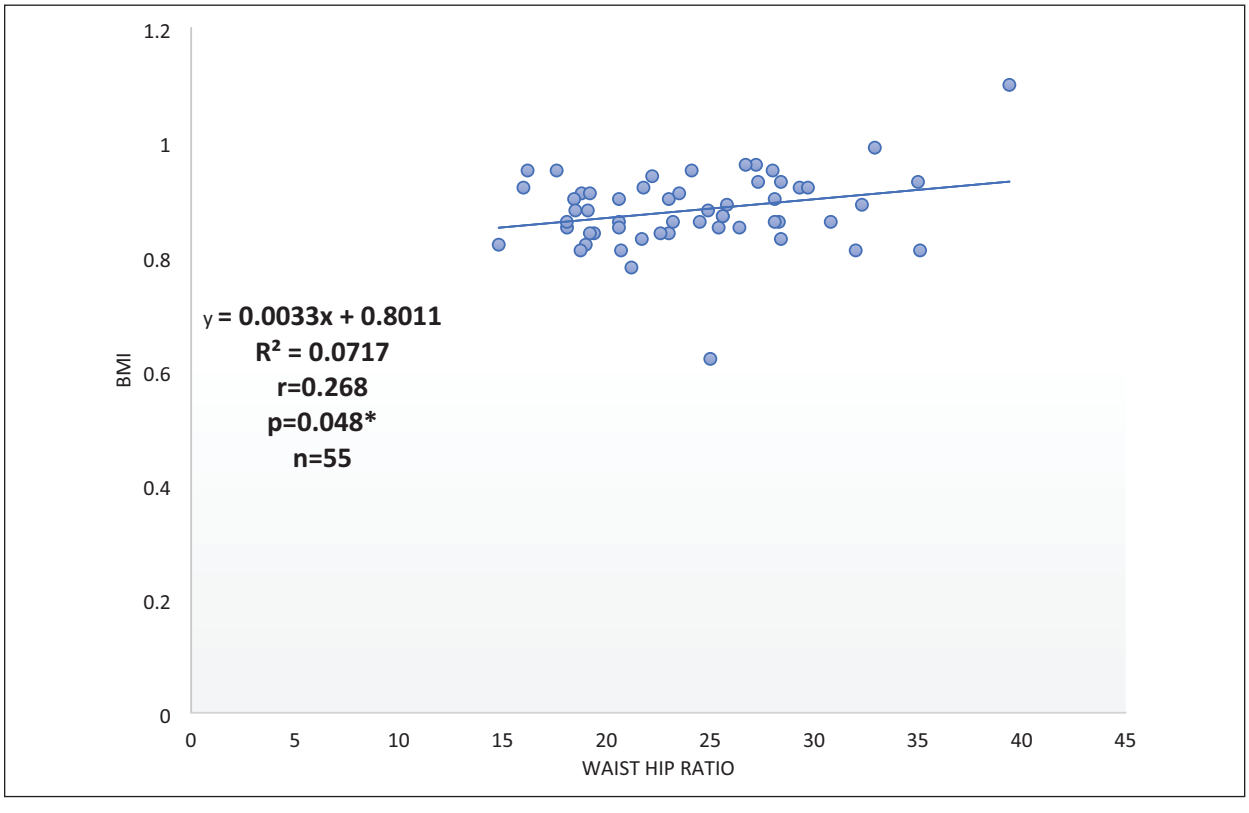

Figure 3. Correlation plot of Body Mass Index (BMI) against Waist-Hip Ratio (WHR).

Discussion

The nutritional status of older adults in Calabar Metropolis is of significant concern. This study aimed to evaluate the nutritional indices and associated risk factors of malnutrition among this population. The findings indicated that 58.2% of older adults were at risk of malnutrition, 9.1% had poor nutritional status, and 32.7% had normal nutritional status. These results align with studies such as Krishnamoorthy et al. (2018), which

reported similar rates of malnutrition and risk of malnutrition among older adults. Malnutrition was particularly higher among dependent older adults (66.7%), likely due to mobility limitations and the inability of caretakers to meet their nutritional needs. A significant relationship was found between activities of daily living (ADL) dependency and nutritional status, with those requiring assistance being more at risk of malnutrition (87.5%; $p < .05$). This is consistent with Salleh et al. (2021) and Vandewoude et al. (2019), who reported that ADL dependency is associated with higher risks of malnutrition and frailty.

The study found significantly higher systolic and diastolic blood pressure, total protein, and albumin levels in older adults compared to younger adults ($p < .05$). This is in line with Cho et al. (2012), which links higher serum albumin levels with higher blood pressure. As individuals age, vascular compliance decreases due to arterial stiffening, leading to an increase in systolic and diastolic blood pressure (Gary, 2014). This is a well-documented phenomenon where the loss of elasticity in the arterial walls increases resistance to blood flow, thus raising blood pressure (Franklin et al., 1997; Frith & Loprinzi, 2018). The higher blood pressure observed in older adults in our study is consistent with these age-related vascular changes. Higher levels of total protein and albumin in older adults might reflect changes in protein metabolism and liver function that accompany aging. Albumin, a key protein produced by the liver, often increases in response to mild chronic inflammation, which is more common in older adults due to various age-related conditions (Morley, 2001). This inflammatory response can elevate serum albumin levels as part of the body's effort to maintain homeostasis (Isong et al., 2022). Additionally, Cho et al. (2012) found a correlation between higher serum albumin levels and elevated blood pressure, suggesting that these biochemical changes may be interrelated in the aging population. Furthermore, the observed increase in total protein levels may also result from the body's adaptive mechanisms to maintain adequate nutrition and physiological balance under conditions of chronic stress and inflammation, which are more prevalent in older adults. This aligns with the idea that older adults may have different baseline levels for certain biochemical markers compared to younger adults, influenced by both age and the cumulative effect of environmental and health factors over time (Glazier, 2022). These observations underscore the importance of considering age-specific reference ranges and the underlying physiological processes when evaluating clinical and nutritional status in older adults.

Older females had higher total protein levels than males (Table 3), corroborating findings by Tian et al. (2014). This gender difference may stem from various factors, including hormonal influences, as estrogen can affect protein metabolism (Sciarra et al., 2023). Additionally, differences in body composition, dietary habits, and health status between older men and women could contribute to this disparity (Berner, 2003). Females may also have higher awareness or access to nutrition, leading to better protein intake. These findings highlight the need to consider gender differences in nutritional assessments and interventions for older adults to ensure tailored and effective healthcare strategies.

Total protein levels were lower in institutionalized adults compared to non-institutionalized adults (6.34 ± 0.24 vs. 9.13 ± 4.58), suggesting regular medical checkups in institutions might mitigate chronic disease prevalence and related nutritional deficiencies. Cognitive decline, assessed by calf circumference, was more pronounced in those with poor cognitive status. Calf circumference is a predictor of frailty and cognitive function (Kim et al., 2018; Raji et al., 2010). The study's results support the link between frailty, cognitive decline, and nutritional status.

BMI and calcium levels were higher in those with good nutritional status compared to those at risk of malnutrition or malnourished, aligning with findings from Fukawa et al. (2018) and dos Santos et al. (2005). There was no significant correlation between BMI and albumin, echoing results from Fukawa et al. (2018), which suggest that hypoalbuminemia is not directly indicative of malnutrition (Camina Martín et al., 2014). A significant positive correlation between WHR and BMI was observed, indicating the risk of obesity and related cardiovascular diseases (Gandhi et al., 2010; Nadankutty, 2016).

Conclusion

In conclusion, our study revealed that malnutrition is a significant concern among older adults in Calabar Metropolis, with a high proportion at risk of malnutrition. We found out that activities of daily living dependency, cognitive status, and biochemical markers are crucial factors in determining nutritional status. Notably, our results showed that older females had high protein levels than males, and institutionalized adults had lower protein levels than non-institutionalized adults These findings highlight the need for targeted interventions to address malnutrition and related health complications in this population.

Limitations of the Study

This study has limitations. We did not evaluate lipid profile which could have provided a more comprehensive understanding of cardiovascular health, due to resource constraints and a focus on other critical nutritional markers. Additionally, our sample size was relatively small, particularly in the control group, which may reduce statistical power, due to funding constraints that limited the number of participants we could recruit. Future studies

should consider including lipid profiles. Increasing the sample size in future work is also recommended to strengthen these findings.

Abbreviations

SPB: Systolic blood pressure; DBP: Diastolic blood pressure, MUAC: Mid upper arm circumference; ADL: Activities of daily living; MNA-SF: Mini-Nutritional Assessment Scale-Short Form; WHR: Waist hip ratio.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Consideration

Ethical approval for this study was obtained from the Health Research Ethics Committee (HREC) with reference number (Rec No. CRSMOH/REC/2022/235) of the Ministry of Health, Calabar, Cross River State. All respondents gave written informed consent and information supplied by the respondents were kept highly confidential including their test results.

Consent for Publication

Not applicable.

Availability of Data and Materials

The dataset generated and/or analyzed during this study are not publicly available due to threats to participant privacy but are available from the corresponding author on reasonable request.

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