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Comparative Assessment of Nutritional Status and Anthropometric Parameters of Malaria Infected Subjects

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ABSTRACT

Malaria is a mosquito-borne infectious disease of humans and other animals caused by parasitic protozoans (a type of unicellular microorganism) of the genus *Plasmodium*. This study was designed to assess the nutritional status (serum total protein, albumin, globulin, triglyceride (TG) and total cholesterol) and anthropometric parameters (Body Mass Index (BMI) and Waist Circumference (WC)) of malaria infected subjects in Ekpoma, Edo State and make comparison with that of the control group. A total of one hundred subjects were recruited for this study which consist of fifty (50) malaria infected individuals and fifty (50) apparently healthy subjects which served as control. Subject data such as name, age and gender were obtained. The results of this study revealed that the total protein, TG, cholesterol, globulin and BMI levels were significantly higher ($p<0.05$) in malaria infected subjects when compared with the control. On the contrary, albumin levels were significantly lower ($p<0.05$) in malaria infected subjects when compared with the control. Also, WC levels were not significantly different ($p>0.05$) in malaria infected subjects when compared with the control. TG, albumin and globulin levels were not significantly lower ($p>0.05$) in male subjects when compared with the female subjects. WC levels were not significantly higher ($p>0.05$) in male subjectswhen compared with the female subjects. BMI levels were not significantly different ($p>0.05$) in male subjects when compared with the female subjects. Based on the results of this study, it can be seen that malaria and malnutrition remain real public health problems. Knowledge on the nutritional profile of the population would be of great benefit in setting up an appropriate health program. We therefore suggest that more standardized studies be conducted to highlight the effect of nutrition and micronutrients on immunological status.

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Introduction

Malaria is a mosquito-borne infectious disease of humans and other animals caused by parasitic protozoans (a type of unicellular microorganism) of the genus *Plasmodium* [1]. The disease is often spread via the bite of a female Anopheles mosquito carrying the infection, which allows the organisms in the mosquito's saliva to enter the host's bloodstream. The protists go to the liver in the bloodstream to develop and proliferate [2]. Malaria usually produces fever and headaches, which can worsen and lead to a coma or even death in extreme cases [3]. A large portion of Sub-Saharan Africa, Asia, and the Americas are among the tropical and subtropical regions in which the disease is prevalent, stretching around the equator. Humans can contract and spread the disease caused by five different species of *Plasmodium* [4]. While *Plasmodium ovale* and *Plasmodium malariae* cause a generally milder form of malaria that is rarely lethal, *Plasmodium falciparum* and *Plasmodium vivax* account for the great majority of deaths caused by malaria [5]. In addition to causing malaria in macaques, the Southeast Asian zoonotic species *Plasmodium Knowlesi* can inflict serious illnesses on humans. Because warm temperatures, stagnant water, and rainfall create perfect conditions for mosquito larvae to thrive, malaria is common in tropical and subtropical climates [6]. By employing insect repellents and mosquito-treated nets to avoid mosquito bites, as well as mosquito-control techniques including insecticide spraying and draining stagnant water, disease transmission can be minimized [7]. Generally, blood films or antigen-based quick diagnostic tests are used to examine blood under a microscope in order to identify malaria [8]. Although there are more sophisticated and expensive methods that use the polymerase chain reaction to identify the parasite's DNA, these are not commonly applied in malaria-endemic regions [9]. According to estimates from the World Health Organization, there were 219 million malaria cases with documentation in 2010. Between 660,000 and 1.2 million individuals were died by the epidemic in that year, majority of them being African children [10]. Since many rural areas lack reliable statistics and many instances go unreported, it is impossible to determine the precise number of deaths [11].

Lipids, also known as fats, are a diverse class of organic compounds that are insoluble in water [12]. A lipid panel, often referred to as a lipid profile, is a collection of blood tests primarily used for screening lipid disorders, such as abnormal levels of cholesterol and triglycerides [13]. These test results are essential for diagnosing certain genetic conditions and estimating risks for cardiovascular diseases, specific types of pancreatitis, and other related illnesses [13]. A lipid profile is particularly important for assessing coronary heart disease risks [14,15]. It offers a reliable prediction of potential heart attacks or strokes caused by hardened or blocked arteries, a condition termed atherosclerosis.

Total protein measures the total amount of protein in serum or blood plasma. Albumin and globulin are the two types of protein found in plasma. The globulin is composed of α1, α2, β, and γ globulins. Protein electrophoresis can be used to quantify these fractions; nevertheless, the total protein test approximates the sum of all fractions [16]. The most prevalent protein in human blood plasma is albumin and it is produced in the liver. It is monomeric and soluble. Preproalbumin, the precursor to albumin, is produced in the liver and has an N-terminal peptide that is cut off before the developing protein is discharged from the rough endoplasmic reticulum. To create the secreted albumin, the product, proalbumin, is cleaved in the Golgi vesicles [17]. Blood albumin concentrations are measured in the reference range of 3.4 to 5.4 g/dL. Compared to albumins, the globulins are a family of globular proteins with larger molecular weights and water solubility values. The immune system produces some globulins, while the liver produces others. The three main blood proteins are fibrinogen, albumin, and globulins. Blood globulin concentrations are typically between 2.6 and 4.6 g/dL [18].

Malaria poses a threat to around 40% of the global populace across more than 100 nations. Approximately 90% of malaria cases worldwide are found in Sub-Saharan Africa [19, 20, 21]. It not only directly threatens health through its infectious nature but also exerts indirect effects by altering nutritional status. The parasite triggers a range of physiological changes that can deplete critical nutrients, disrupt protein synthesis, and exacerbate conditions like anemia and hypoalbuminemia. Such disruptions are particularly concerning in populations where baseline nutritional deficiencies are already prevalent. Understanding these impacts is crucial to mitigating the long-term consequences of malaria on overall health and well-being. This study was therefore undertaken to evaluate the nutritional status and anthropometric parameters of individuals infected with malaria in Ekpoma, Edo State. Specifically, it focuses on assessing serum levels of total protein, albumin, globulin, triglycerides, and total cholesterol. By comparing these findings with those of a control group, this research aims to elucidate the relationship between malaria and nutritional status, providing insights that could inform better clinical management and public health strategies in malaria-endemic regions.

Materials and Methods

Area of Study

This study was carried out in Ekpoma, the administrative headquarters of Esan West Local Government Area of Edo State, Nigeria. The area proper lies between latitudes $6^0$43' and $6^0$45' North of the Equator and longitudes $6^0$6' and $6^0$8' East of the Greenwich Meridian [22]. Ekpoma is made up of many quarters including Eguare, Iruekpen, Emaudo, Ujoelen, Ihumudumu, Illeh, Uke, Uhiele, Ujemen, Ukpenu, Idoa, Ukhun, Egoro, Emuhi, Igor and Idumebo. The following quarters, Eguare, Ujoelen, Ihumudumu, Emuado, and Iruekpen are all considered in this study. Ekpoma has a population of 89,628 and 127,718 at the 1991 and 2006 population census respectively majority of which are civil servants, traders, businessmen/women, transporters, farmers, teachers/lecturers and students by occupation. The samples were examined in the Research Diagnostic Laboratory, of the department of Medical Laboratory Science, College of Medicine, Ambrose Alli University, Ekpoma.

Study Population

A total of one hundred subjects were recruited for this study which consist of fifty (50) malaria infected individuals and fifty (50) apparently healthy subjects which served as control. Subject data such as name, age and genderwere obtained. The age ranges of the subjects were from 20-70 years.

The sample size (N) is calculated from the formula below.

$$\text{Sample side (N)} = \frac{Z^2Pq,}{d^2}$$

Where;
N= the desired size
Z= 1.96(standard score)
P= Prevalence (7%) (0.07)
q= 1-P (0.92)

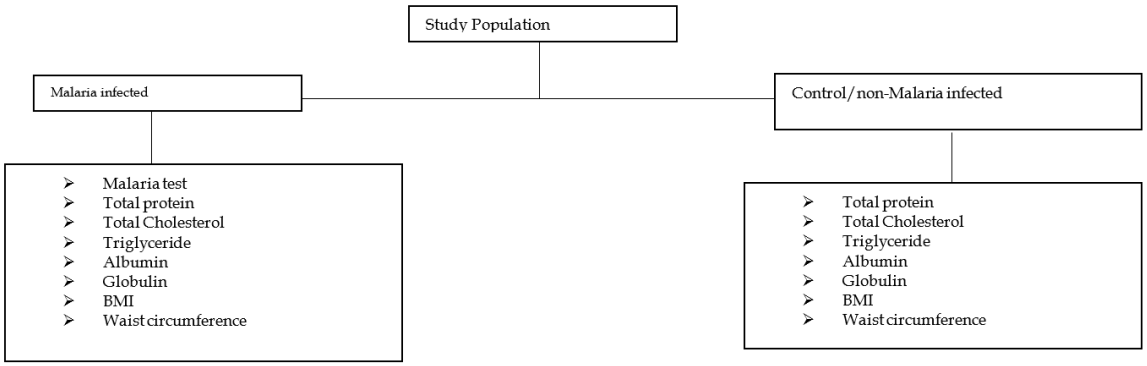
d= sample error tolerated (0.05)

$$N = \frac{1.96^2 \times 0.07 \times 0.92}{0.05} = 98.9 = 100$$

Research Design

The research is designed to assess the nutritional status (serum total protein, albumin, globulin, triglyceride and total cholesterol) and anthropometric parameters of malaria infected subjects in Ekpoma, Edo State and make comparison with that of the control group. Malaria test was done on the malaria infected subjects to confirm they were malaria infected. This study was carried out within three (3) months. A complete record of medical history was obtained for each subject, including name, age, body mass index, waist circumference and duration of malaria infection.

Research Design Chat



Inclusion and Exclusion Criteria

Malaria infected subjects were used for this study. However, subjects with any trace of other illness were not recruited for this study based on the response of the subjects. Also, apparently healthy subjects served as the control group.

Sample Collection

Blood samples (5mls) was collected by vene-puncture into an accurately labelled ethylenediaminetetraacetic acid (EDTA) containers (for subjects) and lithium heparin containers for both subjects and control individuals. The blood samples were centrifuged with a laboratory centrifuge at 4000rpm for 10minutes at room temperature within two hours of collection and the serum separated into clean plain containers which are labelled corresponding to the initial blood samples containers. Analysis was carried out for total cholesterol, triglyceride, serum total protein, albumin, globulin and malaria.

Sample Analysis

Body Mass Index Assessment

Weight was measured after removal of shoes while wearing light clothing. Height was measured without shoes in the standing position with the shoulders in relaxed position and arms hanging freely. BMI was calculated as weight (kg)/height in meter. The classification of BMI according to WHO, is as follows:

- Less than 18.5-Under weight
- 18.5-24.9 - Healthy weight range
- 25.0-29.9 - Over weight
- More than 30.0-Obese.

Waist Circumference Assessment

Waist circumference was measured using a measuring tape over the unclothed abdomen, with measurements made halfway between the lower border of the ribs and the highest point of iliac crest (at the umbilicus level) in the standing position. Participants with waist circumference of 80-87.9 cm were classified as overweight and with >88.0 cm were classified as obese [23].

Malaria Parasite Density Determination

The malaria parasite density was determined by examining a thick blood film stained by Giemsa method [24]. This was done by examining a thick blood film stained using the Giemsa method. To prepare the slide, the blood sample was gently mixed by inversion to ensure uniformity. A clean, grease-free slide was selected, and a drop of blood was carefully placed on it using a Pasteur pipette. A thick smear was made and left to air dry. Once dry, the smear was flooded with diluted Giemsa stain (at a ratio of 1:10) and allowed to stain for 45 minutes. After staining, the slide was rinsed with buffered distilled water (pH 7.0) and gently blotted dry with cotton wool. The slide was then left to air dry completely before being examined under a microscope using a 100x objective lens with immersion oil, allowing for precise observation of the malaria parasite density.

Classification of the Degree of Parasitaemia

The malaria parasite density was graded as follows:

- parasite/field: low density (+)
- 2-9 parasites/field: medium density (++)
- More than 20 parasites/field: high density (+++)

Estimation of Total Protein

Total protein levels in the sample were determined using the method described by [24, 25]. In this process, the biuret reaction occurs when copper ions (Cu2+) form a chelate complex with the peptide bonds of proteins in an alkaline solution, resulting in the formation of a violet-colored complex. The intensity of this color is directly proportional to the concentration of protein in the sample, and its absorbance is measured colorimetrically. For

the procedure, 1.0 mL of biuret reagent was added to test tubes labeled for the blank, standard, and sample. A 20 µL volume of both the sample and standard were then added to their respective tubes, followed by mixing and incubation at 37°C for 10 minutes. After incubation, the absorbance was measured at 540 nm against a reagent blank. The protein concentration in the sample was determined by comparing the absorbance to that of the standard, providing an accurate quantification of total protein..

Determination of Total Cholesterol

Total cholesterol levels were determined using the enzymatic endpoint method (CHOD-PAP) as described by [26] In this method, cholesterol esterase catalyzes the hydrolysis of esterified cholesterol to free cholesterol. The free cholesterol is then oxidized by cholesterol oxidase, producing hydrogen peroxide. This hydrogen peroxide reacts with phenol and 4-aminoantipyrine in the presence of peroxidase to form a red quinoneimine dye complex. The intensity of the color produced is directly proportional to the amount of cholesterol in the sample. For the procedure, 10 microliters of distilled water, the standard, and the sample were dispensed into test tubes labeled appropriately. To each test tube, 1 milliliter of cholesterol reagent was added. The tubes were mixed thoroughly and incubated at 37°C for 5 minutes. The absorbance of both the standard and the samples was measured at a wavelength of 500 nm using a spectrophotometer. The concentration of cholesterol in the sample was then determined by comparing the absorbance of the test samples to that of the standard.

Determination of Triglycerides

Triglyceride levels were determined using the colorimetric method described by [27]. The principle of this method is based on the hydrolysis of triglycerides into glycerol and fatty acids by lipoprotein lipase. The glycerol produced, in the presence of ATP and glycerol kinase, is converted into glycerol-3-phosphate, which is then oxidized by glycerol phosphate oxidase to generate hydrogen peroxide. This hydrogen peroxide reacts with phenolic compounds and 4-aminoantipyrine under the catalytic action of peroxidase, resulting in the formation of a red-colored quinoneimine dye complex. The intensity of the resulting color is directly proportional to the amount of triglycerides in the sample. For the procedure, 10 microliters of distilled water, standard, and sample were dispensed into test tubes labeled appropriately. One milliliter of triglyceride reagent was added to each tube, and the contents were thoroughly mixed before being incubated in a water bath at 37°C for 5 minutes. The absorbance of both the standard and the samples was then measured at a wavelength of 500 nm using a spectrophotometer. The concentration of triglycerides in the sample was determined by comparing the absorbance of the test samples to that of the standard.

Estimation of Albumin

Albumin concentration in the sample was determined using the method described by [50]. This technique is based on the specific binding of bromo-cresol green (BCG), an anion dye, with albumin at an acidic pH, which results in a shift in the absorption wavelength of the complex. The intensity of the color formed is directly proportional to the concentration of albumin in the sample. For the procedure, 2.0 mL of bromo-cresol green reagent was added to test tubes labeled blank, standard, and sample. Ten microliters of both the sample and the standard were introduced into their respective tubes, mixed thoroughly, and allowed to stand for 1 minute at room temperature. The absorbance was then measured at a wavelength of 630 nm using a spectrophotometer, with the reagent blank serving as the reference. The concentration of albumin in the sample was determined by comparing the absorbance of the sample to that of the standard.

Estimation of Globulin

Plasma globulin concentration was estimated indirectly by subtracting the albumin concentration from the total protein concentration, as outlined by [24]. This method involves first determining the total protein level in the sample, followed by the measurement of albumin concentration. The plasma globulin concentration is then calculated by subtracting the albumin value from the total protein value. This approach provides a reliable estimate of globulin levels in the plasma, reflecting the balance between albumin and globulin proteins in the blood.

Statistical Analysis

The result was presented using tables. Data was analyzed using the SPSS software. The percentage prevalence was calculated in each case. Comparative analysis of the result was done using Chi-square statistical software and $p<0.05$ was considered statistically significant. Differences in means were analyzed using Student's t test.

Results

This study assessed the total protein, albumin, globulin, cholesterol, TG, WC and BMI levels in malaria infected subjects. The results in table 1 showed that total protein levels were significantly higher ($p<0.05$) in malaria infected subjects (8.20±3.35 g/dl) when compared with the control (6.94±3.46 g/dl). On the contrary, albumin levels were significantly lower ($p<0.05$) in malaria infected subjects (2.84±1.85 g/dl) when compared with the control (6.74±0.53 g/dl). Globulin levels were significantly higher ($p<0.05$) in malaria infected subjects (7.02±0.39 g/dl) when compared with the control (2.94±1.80 g/dl). Also, cholesterol levels were significantly higher ($p<0.05$) in malaria infected subjects (356.28±200.00 mg/dl) when compared with the control (163.34±67.31 mg/dl). Also, TG levels were significantly higher ($p<0.05$) in malaria infected subjects (119.48±86.34 mg/dl) when compared with the control (87.44±56.06 mg/dl). On the contrary, WC levels were not significantly different ($p>0.05$) in malaria infected subjects (75.96±10.18 cm) when compared with the control (77.60±7.94 cm). BMI levels were significantly higher ($p<0.05$) in malaria infected subjects (26.46±4.46 kg/m^2) when compared with the control (23.51±3.84 kg/m^2).

Table 1: Comparison of Total Protein, Albumin, Globulin, Cholesterol, TG, WC and BMI Levels in Malaria Infected Subjects and Control

Parameters	Control (n=50)	Tests (n=50)	t value	P value
Total Protein (g/dl)	6.94±3.46	8.20±3.35	1.847	0.008
Albumin (g/dl)	6.74±0.53	2.84±1.85	14.323	0.000
Globulin (g/dl)	2.94±1.80	7.02±0.39	5.624	0.000
Cholesterol (mg/dl)	163.34±67.31	356.28±20.00	6.407	0.000
TG (mg/dl)	87.44±56.06	119.48±86.34	2.201	0.030
WC (cm)	77.60±7.94	75.96±10.18	0.898	0.371
BMI (kg/m^2)	23.51±3.84	26.46±4.46	3.547	0.001

KEYS: n=Sample size, p>0.05= Not significant, p<0.05= Significant, BMI- Body Mass Index, TG-Triglyceride, WC- Waist Circumference

The results in table 2 showed the comparison of total protein, albumin, globulin, cholesterol, TG, WC and BMI levels in malaria infected subjects between male control and male test. The results showed that total protein levels were not significantly higher (p>0.05) in male subjects (8.58±3.64 g/dl) when compared with the male control (6.79±3.08 g/dl). On the contrary, albumin levels were significantly lower (p<0.05) in male subjects (3.16±1.84 g/dl) when compared with the male control (6.82±0.55 g/dl). Globulin levels were significantly higher (p<0.05) in male subjects (6.99±0.36 g/dl) when compared with the male control (2.31±1.74 g/dl). Cholesterol levels were significantly higher (p<0.05) in male subjects (380.38±227.14 mg/dl) when compared with the male control (180.00±68.84 mg/dl). TG levels were not significantly higher (p>0.05) in male subjects (114.91±78.26 mg/dl) when compared with the male control (91.83±51.83 mg/dl). WC levels were not significantly lower (p>0.05) in male subjects (77.65±4.42 cm) when compared with the male control (80.17±8.76 cm). BMI levels were significantly higher (p<0.05) in male subjects (26.00±2.74 kg/m2) when compared with the male control (23.46±3.78 kg/m^2).

Table 2: Comparison of Total Protein, Albumin, Globulin, Cholesterol, TG, WC and Bmi Levels in Male Control and Male Malaria Infected Subjects

Parameters	Control (n=24)	Tests (n=26)	t value	P value
Total Protein (g/dl)	6.79±3.08	8.58±3.64	1.870	0.068
Albumin (g/dl)	6.82±0.55	3.16±1.84	9.355	0.000
Globulin (g/dl)	2.31±1.74	6.99±0.36	13.285	0.000
Cholesterol (mg/dl)	180.00±68.84	380.38±227.14	4.147	0.000
TG (mg/dl)	91.83±51.83	114.91±78.26	1.219	0.229
WC (cm)	80.17±8.76	77.65±4.42	1.296	0.201
BMI (kg/m^2)	23.46±3.78	26.00±2.74	2.746	0.008

KEY: n=Sample size; p>0.05= Not significant; p<0.05= Significant

The results in table 3 showed the comparison of total protein, albumin, globulin, cholesterol, TG, WC and BMI levels in malaria infected subjects between female control and female test. The results showed that total protein levels were not significantly different (p>0.05) in female subjects (7.79±3.04 g/dl) when compared with the female control (7.08±3.84 g/dl). Albumin levels were significantly lower (p<0.05) in female subjects (2.49±1.82 g/dl) when compared with the female control (6.67±0.51 g/dl). Globulin levels were significantly higher (p<0.05) in female subjects (7.05±0.43 g/dl) when compared with the female control (3.53±1.67 g/dl). Cholesterol levels were significantly lower (p<0.05) in female subjects (330.17±171.72 mg/dl) when compared with the female control (147.96±63.31 mg/dl). TG levels were not significantly higher (p>0.05) in female subjects (124.42±95.78 mg/dl) when compared with the female control (83.38±60.44 mg/dl). WC levels were not significantly different (p>0.05) in female different (74.13±13.89 cm) when compared with the female control (75.23±6.39 cm). BMI levels were significantly higher (p<0.05) in female subjects (26.96±5.80 kg/m^2) when compared with the female control (23.57±3.96 kg/m^2).

Table 3: Comparison of Total Protein, Albumin, Globulin, Cholesterol, TG, WC and BMI Levels in Female Control and Female Malaria Infected Subjects

Parameters	Female Control (n=24)	Female Tests (n=26)	t value	P value
Total Protein (g/dl)	7.08±3.84	7.79±3.04	0.719	0.475
Albumin (g/dl)	6.67±0.51	2.49±1.82	11.136	0.000
Globulin (g/dl)	3.53±1.67	7.05±0.43	10.024	0.000
Cholesterol (mg/dl)	147.96±63.31	330.17±171.72	5.054	0.000
TG (mg/dl)	83.38±60.44	124.42±95.78	1.827	0.074

WC (cm)	75.23±6.39	74.13±13.89	0.366	0.716
BMI (kg/m^2)	23.57±3.96	26.96±5.80	2432	0.019

KEY: n=Sample size; p>0.05= Not significant; p<0.05= Significant

The results in table 5 showed the comparison of total protein, albumin, globulin, cholesterol, TG, WC and BMI levels in malaria infected subjects according to age. The results showed a non significant increased in total protein levels were higher in subjects within the age range 18-25 years (8.36±3.41 g/dl) when compared with subjects within the age range of 26-30 years (7.53±2.85 g/dl) and 31 years and above (7.85±4.28 g/dl). Albumin levels are higher within the age range of 18-25 years (3.03±1.92 g/dl) when compared with 26-30 years (2.02±1.72 g/dl) and 31 years and above (2.43±1.17 g/dl). Globulin levels are higher within the age range of 31 years and above (7.17±0.13 g/dl) when compared with 18-25 years (7.00±0.42 g/dl) and 26-30 years (7.03±0.34 g/dl). Cholesterol levels were higher within the age range of 18-25 years (361.46± 219.37 mg/dl) when compared with 26-30 years (352.43± 140.14 mg/dl) and 31 years and above (312.500± 121.45 mg/dl). TG levels are higher within the age range of 31 years and above (143.00± 67.21 mg/dl) when compared with 18-25 years (121.08±85.59 mg/dl) and 26-30 years (97.14± 106.09 mg/dl). WC levels are higher within the age range of 26-30 years (78.43±16.22 cm) when compared with 18-25 years (76.08±8.43 cm) and 31 years and above (70.50±14.62 cm). BMI levels were higher within the age range of 31 years and above (28.40±4.58 kg/m^2) when compared with 18-25 years (26.35±4.22 kg/m^2) and 26-30 years (26.00±5.99 kg/m^2).

Table 5: Comparison of Total Protein, Albumin, Globulin, Cholesterol, TG, WC and BMI Levels of Malaria Infected Subjects According to Age

Parameters	18-25 Years (n=39)	26-30 years (n=7)	31yrs & above (n=4)	F-value	P value
Total Protein (g/dl)	8.36±3.41^a	7.53±2.85 ^{a}	7.85±4.28 ^{a}	0.199	0.820
Albumin (g/dl)	3.03±1.92 ^{a}	2.02±1.72 ^{a}	2.43±1.17 ^{a}	0.976	0.384
Globulin (g/dl)	7.00±0.42 ^{a}	7.03±0.34 ^{a}	7.17±0.13 ^{a}	0.323	0.726
Cholesterol (mg/dl)	361.46± 219.37 ^{a}	352.43± 140.14 ^{a}	312.500± 121.45 ^{a}	0.104	0.901
TG (mg/dl)	121.08±85.59 ^{a}	97.14± 106.09 ^{a}	143.00± 67.21 ^{a}	0.380	0.686
WC (cm)	76.08±8.43^a	78.43±16.22 ^{a}	70.50±14.62^a	0.776	0.466
BMI (kg/m^2)	26.35±4.22^a	26.00±5.99 ^{a}	28.40±4.58^a	0.418	0.661

KEY: n=Sample size; p>0.05= Not significant; p<0.05= Significant
Values in a row with the same superscript are not significantly different at p<0.05

The results in table 6 showed the comparison of of total protein, albumin, globulin, cholesterol, TG, WC and BMI levels in malaria infected subjects according to their malaria densities. The results showed a non significant increase in total protein levels were lower in subjects with plus 1 (7.52±3.33g/dl) when compared with subjects having plus 2 (8.52±3.57 g/dl) and plus 3 malaria densities (8.81±2.69 g/dl). Albumin levels are higher in subjects with plus 2 (3.05±2.08 g/dl) when compared with subjects having plus 3 (2.67±1.40 g/dl) and plus 1 (2.61±1.72 g/dl). Globulin levels were lower in subjects with plus 2 (6.98±0.41 g/dl) when compared with subjects having plus 1 (7.06±0.42 g/dl) and plus 3 (7.05±0.27 g/dl). Cholesterol levels were higher in subjects with plus 1 (411.33± 187.14 mg/dl) when compared with plus 2 (327.20± 213.78 mg/dl) and plus 3 (318.57± 192.23 mg/dl). Also, TG levels are higher in subjects with plus 1 (134.44± 90.50 mg/dl) when compared with plus 2 (113.28± 91.94 mg/dl) and plus 3 (103.14± 52.12 mg/dl). WC levels are lower in subjects with plus 1 (74.50± 10.74 cm) when compared with plus 2 (76.80±10.97 cm) and plus 3 (76.71±10.18 cm). BMI levels were higher in subjects with plus 1 (27.44± 5.60 kg/m^2) when compared with subjects having plus 2 (26.18±3.91 kg/m^2) and plus 3 malaria densities

Table 6: Comparison of total protein, albumin, globulin, cholesterol, TG, WC and BMI levels of malaria infected subjects according to Malaria Densities

Parameters	Malaria Densities			F value	P value
Total Protein (g/dl)	7.52±3.33 a	8.52±3.57 a	8.81±2.69 a	0.597	0.554
Albumin (g/dl)	2.61±1.72 a	3.05±2.08 a	2.67±1.40 a	0.321	0.727
Globulin (g/dl)	7.06±0.42 a	6.98±0.41 a	7.05±0.27 a	0.207	0.813
Cholesterol (mg/dl)	411.33± 187.14 a	327.20± 213.78 a	318.57± 192.23 a	1.052	0.357
TG (mg/dl)	134.44± 90.50 a	113.28± 91.94 a	103.14± 52.12 a	0.450	0.640
WC (cm)	74.50± 10.74 a	76.80±10.97 a	76.71±10.18 a	0.281	0.756
BMI (kg/m2)	27.44± 5.60a	26.18±3.91 a	24.94±2.50 a	0.889	0.418

KEY: n=Sample size; p>0.05= Not significant; p<0.05= Significant;
BMI- Body Mass Index; TG-Triglyceride; WC- Waist Circumference
Values in a row with the same superscript are not significantly different at p<0.05

Discussion

Malaria is one of the main significant public health problems in several developing countries affecting especially children, a particularly vulnerable population with the highest morbidity and mortality burdens associated with this disease [28,]. Malaria typically coexists with other illnesses and low socioeconomic position, which hinders the affected communities' ability to develop further. According to, malnutrition is one of the most prevalent and concerning conditions that affects both the severity of other health disorders and the development of children [29]. Although the co-occurrence of both disorders has been investigated, little is known about the underlying mechanisms and clinical implications of this relationship. The study site had a considerable impact on the prevalence of malaria. This aligns with several studies that delineate the geographical fluctuations in malaria susceptibility and the significance of environmental variables in the disease's dissemination [30,31]. Micronutrient status, which also affects malaria severity, complicates the anthropometric interaction between diet and malaria [32].

This study revealed significant alterations in biochemical and anthropometric parameters among malaria-infected individuals. Total protein, triglycerides (TG), cholesterol, globulin, and body mass index (BMI) levels were notably higher ($p<0.05$) in malaria-infected subjects compared to the control group (Table 1). Conversely, albumin levels were significantly lower ($p<0.05$) in malaria-infected individuals. Interestingly, waist circumference (WC) showed no significant differences ($p>0.05$) between the two groups. These findings reflect a hallmark of infection: the disruption of protein metabolism and redistribution of protein synthesis patterns [33]. During malaria infection, accelerated absorption of amino acids by hepatic parenchymal cells often results in reduced plasma concentrations of free amino acids, as these are rapidly sequestered from circulation. Concurrently, protein reserves in tissues such as skin and skeletal muscle experience a net reduction. This degradation of body proteins supplies free amino acids to the liver, which are swiftly utilized for synthesizing acute-phase glycoproteins, including globulins [33]. This metabolic adaptation plays a vital role in the host's defense, enhancing immune response by supporting tissue repair, phagocytic activity, and the development of organism-specific immunity [34]. These findings emphasize the complex interplay between malaria infection and nutritional status, highlighting the need for targeted nutritional interventions to mitigate the metabolic impact of the disease.

Because anthropometric measures are used to identify individuals or communities at risk for ill health as well as to plan and monitor health interventions, it is crucial to interpret them correctly [35]. Reference tables are typically available and updated on a regular basis in industrialized nations [36,37,38]. Because local reference tables are frequently unavailable in underdeveloped nations, industrialized nation reference tables are utilized in their place. Our research demonstrates that erroneous rates of (severe) malnutrition were proposed by using US reference tables. Longitudinal follow-up may be beneficial for the interpretation of anthropometric data. The BMI has not been proven to be a reliable indicator of malnutrition and is known to vary amongst ethnic groups, particularly in the lower ranges [39,40]. Diarrhea and abdominal pain—two symptoms associated with malaria—may result in decreased intake and malabsorption of nutrients, respectively [41]. Additionally, parasitemia may negatively impact nutritional status by causing the host to produce proinflammatory cytokines. The findings of this study indicate that the intricate interactions between malaria infection and nutritional status are influenced by the developmental stage of the host. Our results varied among the study's elder individuals. Older participants in this study had worse nutritional status. The immense toll that malaria exacts is not fully comprehended or measured; this situation has been referred to as the "unexamined burden of malaria" [42]. At the national level, malaria has been linked to subpar economic performance, yet the foundation for this association is unclear. According to this study, there is a substantial correlation between nutritional status and malaria, two factors that are essential to economic success. The burden of parasitemia negatively impacts nutritional status in early adolescence. Malaria may continue to affect nutritional status through the development of proinflammatory cytokines after early adolescence.

Depending on the experimental model employed, variations in serum total lipids, cholesterol, and phospholipids during malaria occurred [43]. The malarial participants in this study had significantly decreased albumin levels. The observed decrease in albumin may have resulted from either or both of the following: increased albumin uptake by the infected erythrocytes, or impaired hepatic function for its synthesis and esterification [44,45,46].

According to the substantial elevation in cholesterol, globulin, and triglyceride levels in the sera of malaria patients is generally not specific to the plasmodium strain and is most likely caused by hepatomegaly and parasitaemia [43]. Pre- and post-hepatic processes, respectively, appear to be the likely culprits for the elevated globulin, triglyceride, and cholesterol levels associated with malaria. According to it appears that the parasite itself may be able to trigger this peripheral lipolysis in order to satisfy its own requirements for fatty acids, with the liver absorbing the excess [47].

Conclusion

This study demonstrates that nutritional parameters and BMI were altered in malaria-infected individuals, highlighting the critical relationship between nutrition and malaria. Based on the findings, it can be concluded that malnutrition and malaria remain significant public health issues. However, knowledge of the population's nutritional composition would aid in establishing effective health programs. More rigorous research is needed to explore the role of nutrition and micronutrients in immunity. To further characterize malaria's overall burden, future studies should include measures of economic productivity alongside randomized, placebo-controlled trials involving older children and adults. The Roll Back Malaria campaign must also be affordable and accessible [48-54].

Conflict of Interest

The authors declare no conflicts of interest. The authors alone are responsible for the content and the writing of the paper.

Ethical Permission

Ethical approval was obtained from the University Ethics Committee and also informed consent was sought from the subjects before collection of blood samples.

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