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Susceptibility of ABO and Genotype Blood Groups to *Plasmodium* Infections and Effect of Parasitaemia on Erythrocyte Sedimentation Rate, Haemoglobin and Packed Cell Volume

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Authors' contributions

This work was carried out in collaboration among all authors. Author UCN designed the study, collected blood samples, carried out the bench-work, interpreted the results and prepared the initial manuscript. Author IOO ratified the study proposal, coordinated the study and corrected the manuscript. Author OOI reviewed the manuscript, checked for accuracy and integrity of data and wrote the final manuscript. Author NJ collected blood samples and helped in carrying out the bench-work. All authors read and approved the final manuscript submitted for publication.

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ABSTRACT

Aims: The study focused on "susceptibility of ABO and genotype blood-groups to malaria infection and effects of parasitaemia on erythrocyte sedimentation rate (ESR), haemoglobin (Hb), and packed cell volume (PCV).
Study Design: Cross-sectional descriptive study.
Place and Duration of Study: Primary Health Centers (PHC) in Awka North, Awka South, Onitsha North, and Onitsha South Local Government Areas (LGAs) of Anambra State Nigeria, between January and June 2018.
Methodology: The 800 consenting individuals purposively selected for study were stratified under LGAs, gender, age-groups, ABO blood groups, and haemoglobin genotypes using clinic records. Blood samples were collected by venipuncture, and Giemsa stained thick and thin films were

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examined by microscopy for malaria parasites while ESR, Hb and PCV were determined by standard laboratory procedures. Data was subjected to descriptive statistics to obtain totals, percentages, means and standard error of mean. Error bars indicated significant differences (P<0.05) among variables compared with bar charts in MS Excel version 2010.
Results: Population examined was evenly distributed under LGAs and gender. A total of 436 out of 800 were malaria parasite positive (Overall prevalence=54.4%). About 70% of all infections was due to *Plasmodium falciparum* while *P. malariae, P. ovale* and *P. vivax* contributed 18.1, 14.9 and 0.5%, respectively (P>0.01). Malaria prevalence was higher in ONLGA (60%), males (59%), and children under 10 years (78.5%). Individuals of ABO Blood groups "O" and "A", and genotype "HbAA" were more susceptible to malaria infection than their counterparts. Almost 75% of the infected individuals had elevated ESR and depressed Hb and PCV levels.
Conclusion: Dominant malaria parasite in the area *was P. falciparum*. Children and those of Blood groups 'O' and 'A', and genotype Hb-AA were more vulnerable to *Plasmodium* infections. Malaria-induced anaemia was linked to high ESR and low Hb and PCV levels.
The findings of this study may be helpful to modify the line of action plan to contain malaria in these localities.

Keywords: ABO blood groups; genotypes; ESR; HB; PCV; malaria-induced anaemia.

1. INTRODUCTION

Malaria has remained endemic in tropical and sub-tropical regions of the world because of the characteristic patterns of rainfall, consistent high temperatures and high humidity which aids vector development and survival in these areas [1]. Female *Anopheles* mosquitoes - *Anopheles gambiae*, *A. funestus*, *A. arabiensis*, and *A. moucheti* – have been implicated as malaria parasites vectors in tropical Africa [2,3]. *Plasmodium falciparum* and *P. malariae* co-infections have been encountered in some parts of Africa [1] but in Central and Western Africa, *P. falciparum* is the dominant species [2,4] while *P. vivax* and *P. ovale* infections are uncommon [5].

Malaria accounts for about 60% of outpatient hospital visits, and 11 and 30% of maternal and child mortality respectively, in Nigeria [6] where *P. falciparum* is responsible for about 82% of all infections [7] while *P. malariae* and *P. ovale* account for 14% and 5% respectively [8]. Nigeria had finalized the 'national malaria control strategic plan' to eliminate malaria by 2020 [9]. As Nigeria progresses towards to achieve this plan, it is also very important to look at some haematological profiles that render some individuals more than other very susceptible to *Plasmodium* parasitaemia. The outcome will help to optimize control interventions targeted to specific localities [10].

Residents of Awka North and South Local Government Areas (LGAs) [11,12,13] and Onitsha North and South LGAs [14] of Anambra State, south-eastern Nigeria are experiencing high malaria morbidity, perhaps due to non-compliance to malaria-prevention strategies. Many workers have also reported that ABO-blood groups [2,8,15] and Hb-genotypes [8,16,17,18] are important factors that predispose many individuals and communities to *Plasmodium* infection. However, it is important to also know the effects of *Plasmodium* infections on erythrocyte sedimentation rate (ESR), and on levels of haemoglobin (Hb) and packed cell volume (PCV) since that will help clinicians to differentiate between malaria-induced anaemia and other causes of anaemia. This study was therefore focused on "Susceptibility of ABO blood groups and genotypes to *Plasmodium* infections and the effect of parasitaemia on erythrocyte sedimentation rate, haemoglobin and packed cell volume."

2. MATERIALS AND METHODS

2.1 Study Population

This is a cross-sectional descriptive study involving 800 consenting individuals attending Primary Health facilities in four out of the 21 Local Government Areas (LGAs) in Anambra State, south-eastern Nigeria (Image 1). The LGAs are Awka North LGA (ANLGA), Awka South LGA (ASLGA), Onitsha North LGA (ONLGA), and Onitsha South LGA (OSLGA). Sampled individuals (100 males and 100 females from each LGA) were purposively selected for the study. Ten different persons (five males and five females) were screened weekly at the PHC

of each of the four LGAs between January and June 2018. Inclusion criteria were that the individual must have (a) stayed in the study area for at least four weeks prior to collection of his or her blood sample for examination, (b) registered with the PHC, and (c) not taken anti-malaria medicine two weeks before being examined. Exclusion criteria were that the individual had (a) never stayed for four weeks in the study area prior to examination, (b) not registered with the PHC, and (c) taken anti-malarial medicine of less than two weeks before the examination.

2.2 Considerations

Advocacy visits to the PHCs were undertaken during which time the purpose of the study was explained to the health officers for their co-operation. Health personnel at the PHC also helped to explain.

2.3 Laboratory Investigations

Based on information entered on the Clinic Folders at the PHC, consenting individuals' location (LGA), age, ABO blood groups, and Hb-genotypes were entered in format designed for subsequent laboratory investigations. Blood samples were routinely collected from each individual by venipuncture for Giemsa stained thick and thin blood film microscopy for malaria parasites examination. Erythrocyte sedimentation rate (ESR), and levels of haemoglobin (Hb) and packed cell volume (PCV) for each blood sample were routinely determined in our mobile laboratory. We observed standard operational procedures and laboratory best practices. Prompt treatment was recommended for individuals that tested positive for malaria parasites.

2.4 Data Analysis

Data generated were recorded, collated and entered and processed in MS excel version 2010 (Microsoft Corporation, Redmond Washington, United States of America) for summations, means, standard errors of means, and percentages. Further, bar charts were constructed in MS excel with the obtained secondary data while error bars indicated significant differences (P< .05) among the variables considered.

Image 1. Nigeria (inset) and the 21 LGAs of Anambra State showing the relative locations of the studied ANLGA, ASLGA, ONLGA, and OSLGA (by courtesy of the Department of Geography and Metrology, Nnamdi Azikiwe University Awka, Nigeria)

3. RESULTS

3.1 Distribution of Sample Population

There were even distributions of the sampled population (Fig. 1) among the four LGAs (25% each) and gender (50% each). However, children under 10 years accounted for about 36%, followed by age-group 11-20 years (27%) while those within 21-39 and over 30 years contributed less than 20% each to the population studied. Carriers of Group O contributed about 38% while carriers of groups A, B, and C accounted for about 27, 20 and 15% respectively. No haemoglobin genotype SS carrier participated in the study but carriers of HbAA contributed about 70% while HbAS was 30%.

3.2 Overall Malaria Prevalence in the Sample Population

The overall malaria parasitaemia prevalence was 54.5% (Fig. 2). Onitsha south LGA recorded highest prevalence of 60% among the other three LGAs (range 50.5% - 56%). Gender prevalence in males (59%) was higher than in females (50%). The differences in prevalence between age-groups was highly significant (P<0.01). The infants recorded as high as 78.5% while adolescents and adults of 21-30 and over 30 years were 60, 44 and 37% respectively. Carriers of ABO blood group "O" and "A" were more susceptible to malaria parasites than groups "B" and "AB". No carriers of haemoglobin genotype SS participated in the study but prevalence of malaria among carriers of HbAA and HbAS were 77% and 35%, respectively. *Plasmodium* parasitaemia apparently caused elevated ESR and lowered Hb and PCV levels.

3.3 Prevalence of Malaria Parasite Species in the Sample Population

Plasmodium falciparum was observed to be the dominant malaria parasite species encountered during the study (Fig. 3) and accounted for about 70% of all infections while *P. malariae*, *P. ovale*, and *P. vivax* were responsible for about 18%, 15% and 0.5%, respectively. Falciparum malaria (Fm) prevalence was significantly higher in ONLGA (72.5%) than the other three LGAs (range: 59.8% - 68%) but *P malariae* infection was highest in ASLGA (22.8%). Females recorded higher Fm infection (71.5%) than males (62.5%) but Malariae malaria (Mm) and Ovale malaria (Om) were higher in males. Difference in Fm between age-group of ≥31 years and other age-groups was highly significant (P<0.01). *Plasmodium vivax* infection was seen only among males that were ≥31 years in ONLGA.

3.4 Susceptibility of ABO Blood Groups and Genotypes to *Plasmodium* Infections

The ABO blood groups as well as genotypes AA and AS appeared to be more susceptible to *P. falciparum* than to *P. malariae*, *P. ovale* and *P. vivax* infections (Fig. 4). Blood groups AB and O, and HbAS were apparently not infected by *P. vivax* while individuals that carry HbSS were not encountered in the study. Fig. 4 also indicated the possible effects of *Plasmodium* infections on ESR, Hb and PCV. It was apparent that *Plasmodium* infections could be correlated with elevated ESR, as well as low haemoglobin and PCV levels.

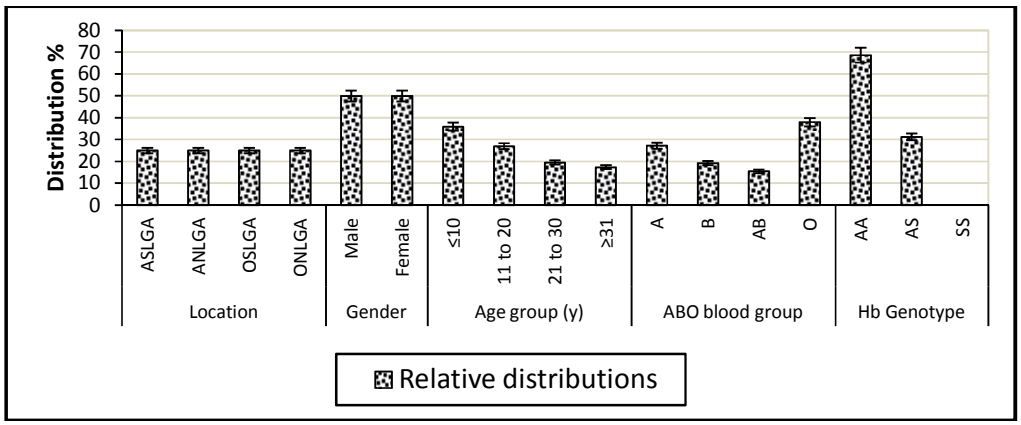

Fig. 1. Percentage distribution of subjects examined for malaria parasitaemia according to locations, gender, age-groups, ABO-blood groups, and genotypes

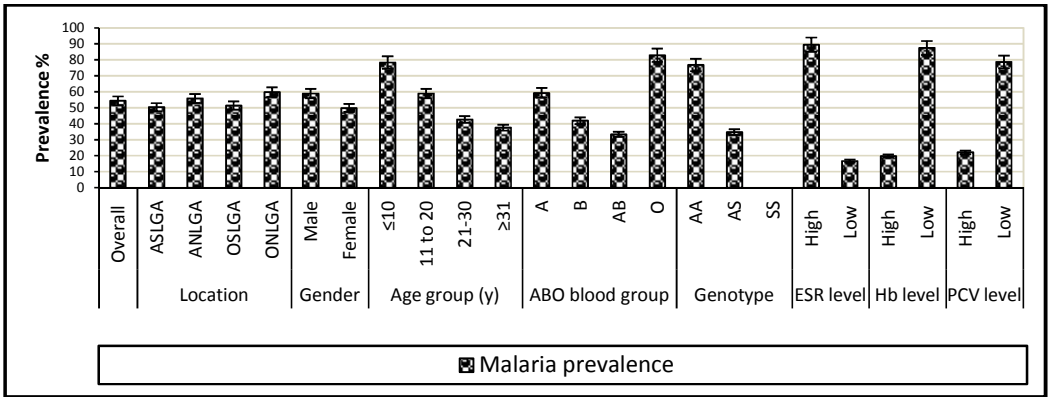

Fig. 2. Overall malaria parasitaemia according to locations, gender, age-groups, ABO blood groups, genotypes and levels of ESR, Hb and PCV in infected individuals

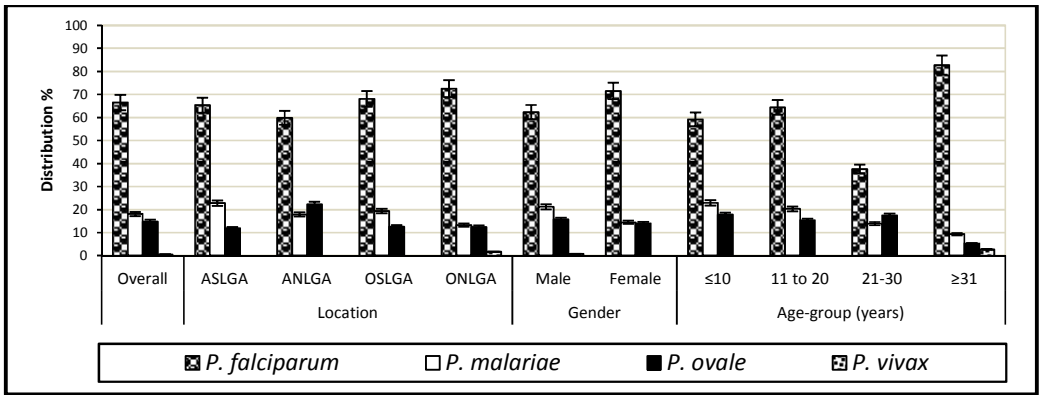

Fig. 3. Distribution of *Plasmodium* infections by LGAs, gender and age-groups

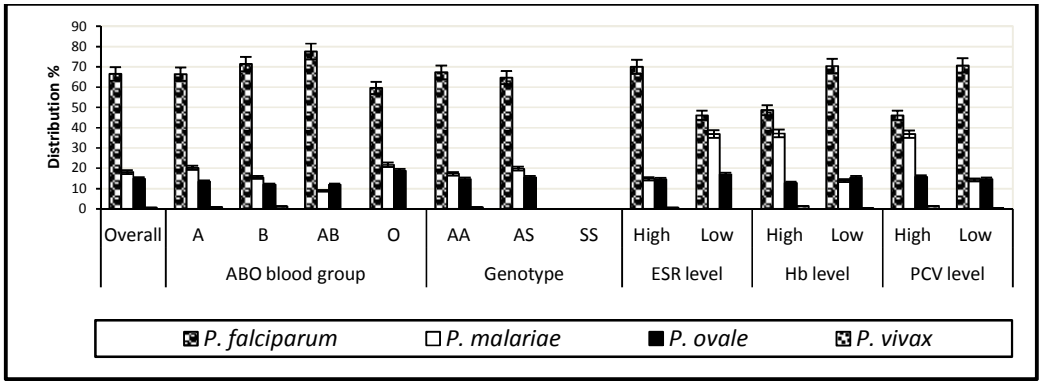

Fig. 4. Distribution of *Plasmodium* species by blood profiles of the individuals

4. DISCUSSION

In the present study, *P. falciparum* was responsible for more than 65% of all malaria infections which confirmed reports that *P. falciparum* is the dominant species of malaria parasite in Nigeria [4,7,8,10,19]. The overall malaria prevalence 54.4% recorded in the present study was similar to 53.9% and 59.6% earlier reported from Ozubulu [20] and Awka [21] respectively. Though considered to be on the high side it showed appreciable improvement on earlier reports of 62.1% from Ogbaru LGA [10], 76.4% from Onitsha Metropolis [22], and Awka

where mixed infections with *P. falciparum* and *P. malariae* (62.1%; 9.3%) and (62.3%; 9.6%) were earlier observed in blood of donors and recipients, respectively [23]. These staggering figures support the opinion that Anambra State and Nigeria as a country have experienced a continuous lack of access and healthcare underutilization of biomedical health services for malaria treatment and has suffered immensely due to poverty [24].

In this study, males (59%) seemed to be generally more infected than females with 50% malaria prevalence. However, females were actually more susceptible to *P. falciparum* infection. These observations were in line with reports from Kano [2], Ogun [8], Iyi-owa Odepke [10], Democratic Republic of Congo [15] and Malawi [25]. These differences might be attributed to the fact that females are endowed with hormonal and genetic factors that enhances their immunity to malaria and other parasitic diseases [2]. Males may be at higher risk of malaria infection due to their exposure and inherent cultural determinants [8]. Hence the repeated exposure to falciparum malaria among males may result in development of partial immunity that renders them at lower risk of *P. falciparum* infection [15].

Prevalence of malaria in the present study was also significantly higher in children than adults, which supported reports from Iyiowa Odekpe in Ogbaru LGA [10], Kenya [26], and West Sumba District of Indonesia [27]. High burden of childhood malaria in endemic regions have also be reported [3]; and increased risk for malaria among younger age-groups in this study suggested that protective immunity against *Plasmodium* infections is acquired with increasing age.

Susceptibility of ABO blood groups to *Plasmodium* infection in the present study was more apparent with carriers of groups “O” and “A”. Several reports support the hypothesis that blood group “A” represents a risk factor for high chance of rosette (which is usually characterized by high *P. falciparum* parasitaemia during malaria infection) [28,29] and a reducing effect of blood group “O” on rosette [30]. Hence, the present finding seemed to substantiate the hypothesis about a selective evolutionary advantage of *P. falciparum* infection on blood group “O” cells compared with other blood group types in areas where malaria is endemic. However, reports from Ghana [31,32] indicated that blood group “O” was the most abundant blood group, and that asymptomatic carriage of *P. falciparum* parasite in a population they studied was not associated with any particular blood group variant or haemoglobin genotype. However, blood samples examined at Awka for susceptibility of ABO blood groups to malaria parasites revealed that carriers of blood group B recorded the highest susceptibility to malaria parasites [12]. Naturally, some individuals are known to be more prone to mosquito bites than others [33]; and it has been observed that females of *Anopheles gambiense* seemed to recognize blood groups and feed preferentially [34]. Although the basis for this recognition was has not been fully elucidated, it had earlier been related to the occurrence of ABO substances on skin cells and in sweat secretions [35,36]. Moreover, there was a report [37] that blood group “O” and “A” had highest and least susceptibility to malaria parasites, respectively. Among pregnant women examined at a maternity in Awka, the ABO blood groups susceptibility to *Plasmodium* infections was in the order: “O”> “A”> “B”> “AB” [38].

With respect to haemoglobin genotypes, this study shows that *Plasmodium* infection was higher among carriers of HbAA than HbAS. No participant with HbSS was enrolled but our finding was consistent with previous studies conducted in various parts of Africa [39,40] though associations between HbAA and HbSS traits and malaria risk have not been uniformly established [41,42]. There is a widely held view that HbSS erythrocytes physical characteristics may confer protection against *Plasmodium* infection by interfering with the growth and multiplication of malaria parasites by the sickle cell trait [43].

In the present study *Plasmodium* parasitaemia caused elevated ESR and lowered Hb and PCV levels in line with the findings [44] at King Saud University where the association of host haematological indices (ESR, Hb and PCV) in falciparum and vivax malaria were elucidated. These authors [44] reported significantly lower haemoglobin and PCV as well as significantly higher ESR in all infection types with *P. vivax*, *P. falciparum* and mixed infections. It was also observed that parasitaemia and temperature were significantly correlated with ESR in vivax infection whereas parasitaemia correlated with PCV in falciparum infection [44]. The fact that malaria infected individuals exhibited low haemoglobin, low PCV, and elevated ESR could

be of advantage to disease or as potential diagnostic marker in malaria infections.

5. CONCLUSION

Plasmodium falciparum was the dominant malaria parasite species encountered in the study area. Individuals under 10 years old, and those in ABO blood-groups 'O' and 'A', as well as genotype HbAA were most susceptible to malaria infections. The correlation of elevated levels in ESR, and depressed Hb and PCV levels were indications for malaria-induced anaemia among these people. The findings of this study may be helpful to modify the line of action plan to contain malaria in these localities.

CONSENT

The purpose of the study to clinic attendees before their informed-consent to participate in the study was obtained.

ETHICAL APPROVAL

Ethical approval for the study was from the Ethical Committee of Chukwuemeka Odumegwu Ojukwu University Teaching Hospital (COOUTH) Awka, Anambra State Nigeria with Reference № COOUTH/AC/Vol.I.XI/00010 of 3rd November 2017.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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