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RESEARCH

Introduction

Malaria remains a major public health concern worldwide, more seriously in sub-Saharan Africa. With over 263 million cases reported worldwide in 2023, sub-Saharan Africa accounted for 94% of the total cases of malaria worldwide [1]. The World Health Organization (WHO), in their Global Technical Strategy for Malaria 2016–2030 publication [2] reported declining rates of malaria episodes from 82 in 2000 to 57 cases per 1000 population in 2019, before increasing to 59 in 2020. Most of these declines have been attributed to scale-up of indoor residual spraying (IRS), long-lasting insecticidal nets (LLINs) usage as well as introduction globally of artemisinin-based combination therapy (ACT) for malaria treatment and intermittent preventive treatment (IPTp) during pregnancy [2]. Despite these intervention efforts, malaria continues to be a major cause of morbidity and mortality worldwide with an estimated 3.2 billion people at risk of being infected and developing the disease [2].

Uganda remains among the five countries that contribute 50% of the global malaria cases [1, 3, 4] and ranks 3rd and 5th highest in mortality and morbidity due to malaria worldwide, respectively [5]. To achieve WHO member states ambitious target of reducing the global malaria burden by 90% by 2030, Uganda has adopted several intervention strategies with the goal of having accelerated nationwide scale-up of universal coverage of cost-effective malaria prevention and treatment interventions [5]. These interventions include mass distribution of LLIN, IRS, larval source management, scale-up malaria diagnostics using microscopy and rapid diagnostics tests

[19]. e current malaria management in this region combines the use of IRS, ITN and home-based management of fever using a village health team. e annual malaria incidence in the region is 52.3 cases per 1000 per month [12].

Study design

Cross-sectional household surveys were conducted in the same households alongside the entomological surveys described in Echodu et al. (2020) during the rainy season in May of 2017, in April, June and September of 2018, and during the dry season in February of 2019. Two sub-counties from each district were randomly selected out of which two villages were chosen at random for study. On average, twelve households were sampled per village for an overall study design of 48 households per district (Agago, 51; Gulu, 51; Kitgum, 43; Oyam, 48). Household observation and physical observation of the LLINs were done simultaneously on interview day.

Ethical standards were maintained throughout the surwith insecticides by the supplier, if treated; (iii) the frequency of bed net treatments; (iv) the individuals who slept under the bed nets; (v) whether the household used insecticides other than bed nets, or in addition to bed nets; and (vi) whether indoor residual spraying was done in the house the previous or any other night. ese categorical variables were coded for data analysis (Supplementary Material 2 and Table S2).

Data analysis

e analysis of the categorical data collected here was geared towards answering the question as to whether an association exists between predictors and episodes of malaria among residents of northern Uganda. e

Table 2 Comparing the effectiveness of malaria control strategies offered by respondents beyond indoor spraying

interview. The contingency Tables 1 and 2, and the bar charts shown in Fig. 2 are provided for some context.

Data properties—exploratory

Overall, the data collected here show an active inclination towards taking measures against the spread of malaria in the study area, particularly the use of insecticides in some form. As can be seen from Fig. 2b and the two-way contingency table, Table 1, the number of households whose malaria-controlling mechanism involves insecticides was 433 (sum 137 + 123 + 173) out of a total of 516. That is, there were 516 direct responses, 433 and 83 of which were yes and no, respectively. (The number 516 (versus 193) is due to the fact that some households practiced up to three of the intervention measures shown.) In details, there were 137 respondents (27% of the total) who carry out indoor residual spraying in their houses and 47 (9% of the total) that did not, 123 (24%) that tested bed nets before treating them and 20 (4%) that did not, and 173 (33%) that used bed nets impregnated or treated with insecticides and 16 (3%) that did not. Note that the 433 yes responses represent 84% of the respondents that had some kind of malaria control.

As mentioned earlier, additional malaria-controlling mechanisms adopted for controlling mosquitoes – the carriers of malaria pathogens – were offered by respondents. They range from cutting grass around homesteads and draining stagnant water pools to not having any strategy. By the number of times these additional control mechanisms were provided (Fig. 2c), the primary one appeared to be the use of a bed net (122 out of 177). This was followed unfortunately, albeit to a minor extent, by not having any form of preventive measure against malaria whatsoever – not even receiving treatment after falling sick (16/177).

Seven households kept grass around houses low ostensibly to deny mosquitoes hiding places during the day, or relied on medical treatment only after becoming sick. A few households reported combining two to three strategies to control malaria. Four households for example combined keeping grass low around houses by using bed nets or keeping doors closed by draining stagnant water pools where mosquitoes might breed.

To assess the relative effectiveness of these different strategies, a simple ratio of the number of malaria episodes and number of times a control mechanism was offered by respondents n was computed for each category for comparison (column s/n in Table 2). The smaller the value of this ratio in comparative terms, the more successful the intervention strategy was. In that context, relying on bed nets for controlling malaria, or combining bed net usage with (i) IRS, (ii) draining stagnant water pool, (iii) clearing grass around the house, or (iv) receiving medical treatment after falling sick had the smallest value at 1.33 and therefore the best strategies among the 22 studied. Note that the ratio was higher for households (i) that relied exclusively on treatment alone or (ii) that had no strategy (1.50 and 2.00, respectively) which clearly shows that the use of bed nets is not only important in controlling malaria in the study area, but that prevention is better than getting treated after falling sick. Furthermore, the worst a household can do by this analysis is to have no strategy at all for controlling malaria – including receiving no medical treatment after falling sick.

Overall, children bore the brunt of malaria in northern Uganda in the three months prior to this survey, irrespective of actions taken to control malaria at the household level.

Selecting number of MCA dimension to retain

The MCA technique was the method of choice here because (i) our questionnaire provided a 22-level categorical dataset containing a mixture of integers and factors, and (ii) non-linear associations were found among the observables by regression (not shown), meaning regression was not appropriate for analysis here. MCA did not only reveal the internal structure of the non-linear correlations observed (as will be shown below), but allowed us to assess relationships which would not have been obvious by regression.

Of the 22 levels of the categorical dataset collected here, MCA yielded 17 important dimensions by decomposing the total MCA inertia (variance in a multivariate dataset) into a possible maximum of 22. Five of these dimensions were identified to have most of the information for inclusion into the final data matrix used in further analysis. The five dimensions accounted for 14.41%, 9.70%, 7.92%, 6.35% and 5.88% of uncorrected inertia, respectively. Uncorrected inertia was used since the information expected from MCA (i.e., the locations of points in the 'cloud of individuals') are unaffected – corrected or not [20, 25].

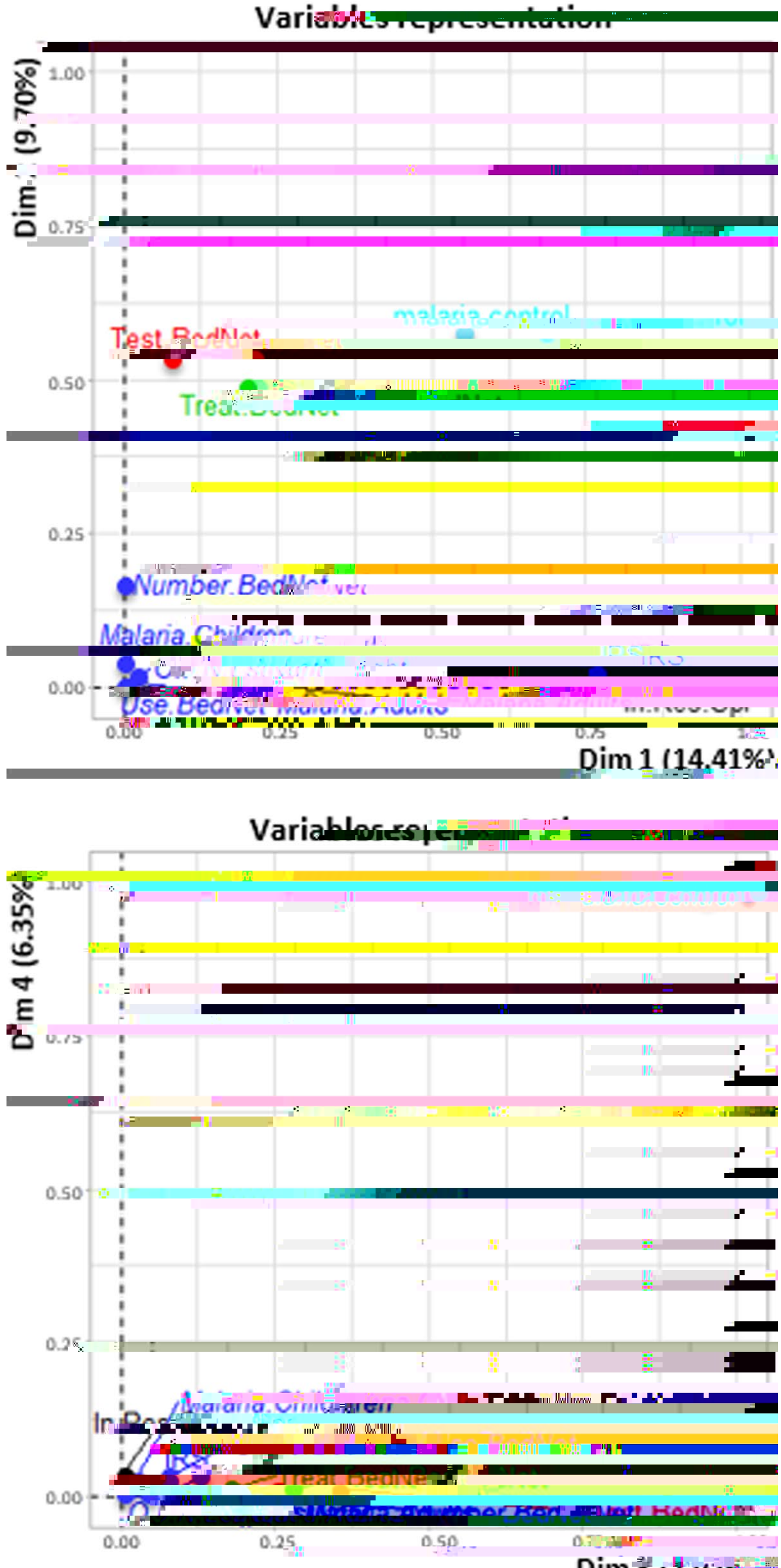

Fig. 3 Variable representation along the first four MCA dimensions showing that (**a**) Dim1 and 2 together represent Test.BedNet, Treat.BedNet, malaria.control, IRS and I.Res.Spr, the five most important predictors of malaria identified MCA, adequately while (**b**) Dim 3 and Dim 4 represent only malaria.control adequately. The first two dimensions therefore explain most of the inertia (variation) contained in the data. Number.BedNet, Use.BedNet, O.N.LstNight, Malaria. Children and Malaria. Adults are supplementary variables added for completeness (see Fig. 4)

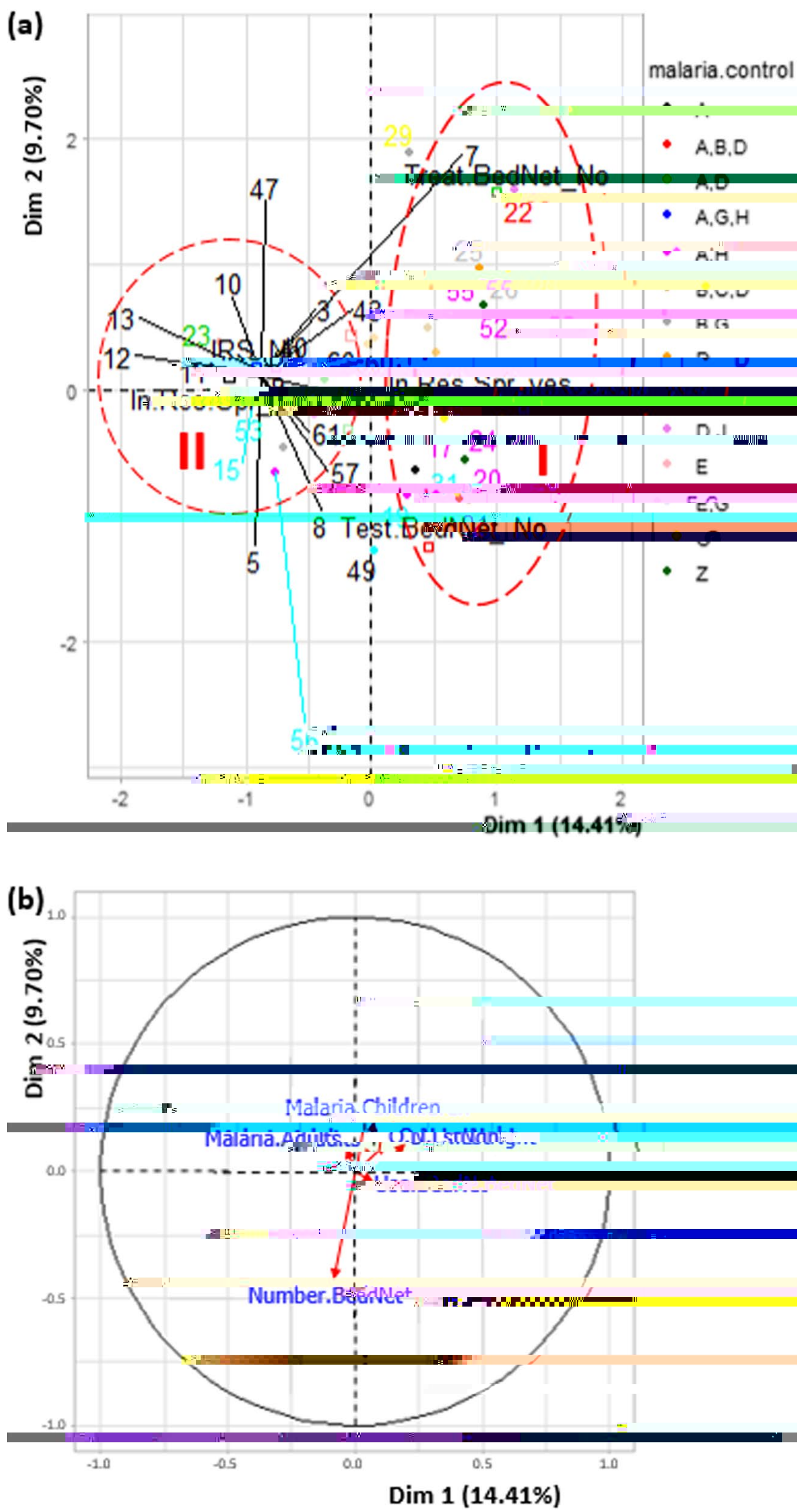

Fig. 4 **a** MCA factor map showing the clustering of 61 of the most contributive households (out of 193) and the five of the most important interventions to the two first two MCA dimensions. Key to Malaria.Control are provided in Fig. 2 caption. **b** Vectors showing the relationships between malaria episodes in children or adults and either the number of people who spent the night before in residential house (O.N.LstNight; used here as surrogate for continual residency in a household), the number of bed nets in households, or the usage of bed nets

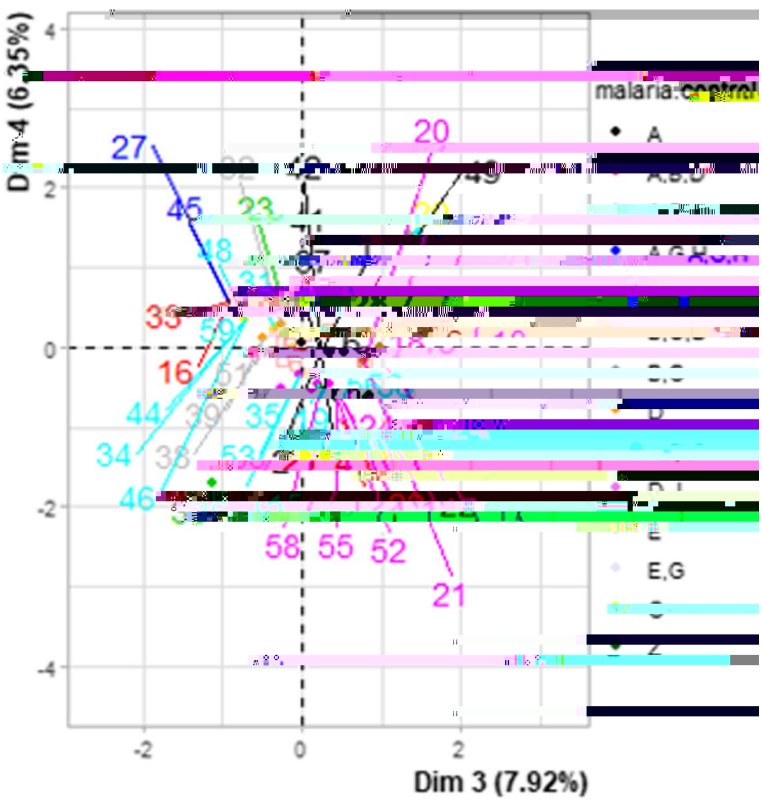

Fig. 5 Factor map showing correlations of the third and fourth dimensions which are mainly with the additional malaria control strategies defined in Fig. 2 caption (A to Z) and not with the major drivers of malaria in northern Uganda

ese households are split 1:1 between non-bed nets users (who score strongly along the dimension) and bed nets users (who scoreless strongly along Dim 1).

e locations of the households that scored strongly (positively or negatively) along Dim 1 are Parabongo in Agago District, Minakulu in Oyam District, Layamo in Kitgum District, and Awach and Unyama in Gulu District. e village-level distributions are as follows: 11 in Pacer Parish in Parabongo sub-county, Agago District (10 in Jinja Village and one in Olwor Nguu), six in Adel Parish, Minakulu sub-county, Oyam (all in Obapo village), two in Abanya Parish, Oyam District (Mot-mot Atwero and Bar Owor, Acaba,), two in Pakwelo Parish, Unyama sub-county, Gulu District (Akonyibedo village) and two in Pagen Parish, Layamo sub-county, Kitgum (Lelamur village), and one household in Gweng Diya Parish in Awach sub-county, Gulu district (Pageya).

Dimension 2 (Dim 2) represented a gradual increase from those households that use treated bed nets (*Treat.BedNet_yes*) without testing them (*Test.BedNet_no*) to those households that test bed nets (*Test.BedNet_yes*) in addition to taking other malaria control measures such as draining water pool (*B*) and keeping grass short around the homestead (*D*). Dim 2 also separates households with bed nets (scoring strongly and negatively) from those without bed nets (scoring strongly and positively). For intervention, the households with bed nets rely mostly in treatment after contracting malaria while the households with no bed nets relies primarily on clearing grasses around the house to remove mosquito hiding places. All households represented by Dim 2 reported at least one household member with malaria in the three months prior to this survey.

To provide actionable items based on alignment along Dim 1 and Dim 2, the vectorial relationship among each of those most important supplementary quantitative predictors are displayed in Fig. 4b. e alignment of the vectors suggests the following: that more than any other intervention strategies studied, incidences of malarial (Malaria. Adults and Malaria. Children) were strongly related to lack of bed nets or lack of use thereof (i.e., Number.BedNets and Use.BedNets vectors point in opposite directions to vectors representing malaria incidences in children and adults), and directly associated with the number of individuals spending a night together in a household (i.e., O.N.LstNight vector points approximately in the same directions as vectors representing malaria incidences). e results also show that more

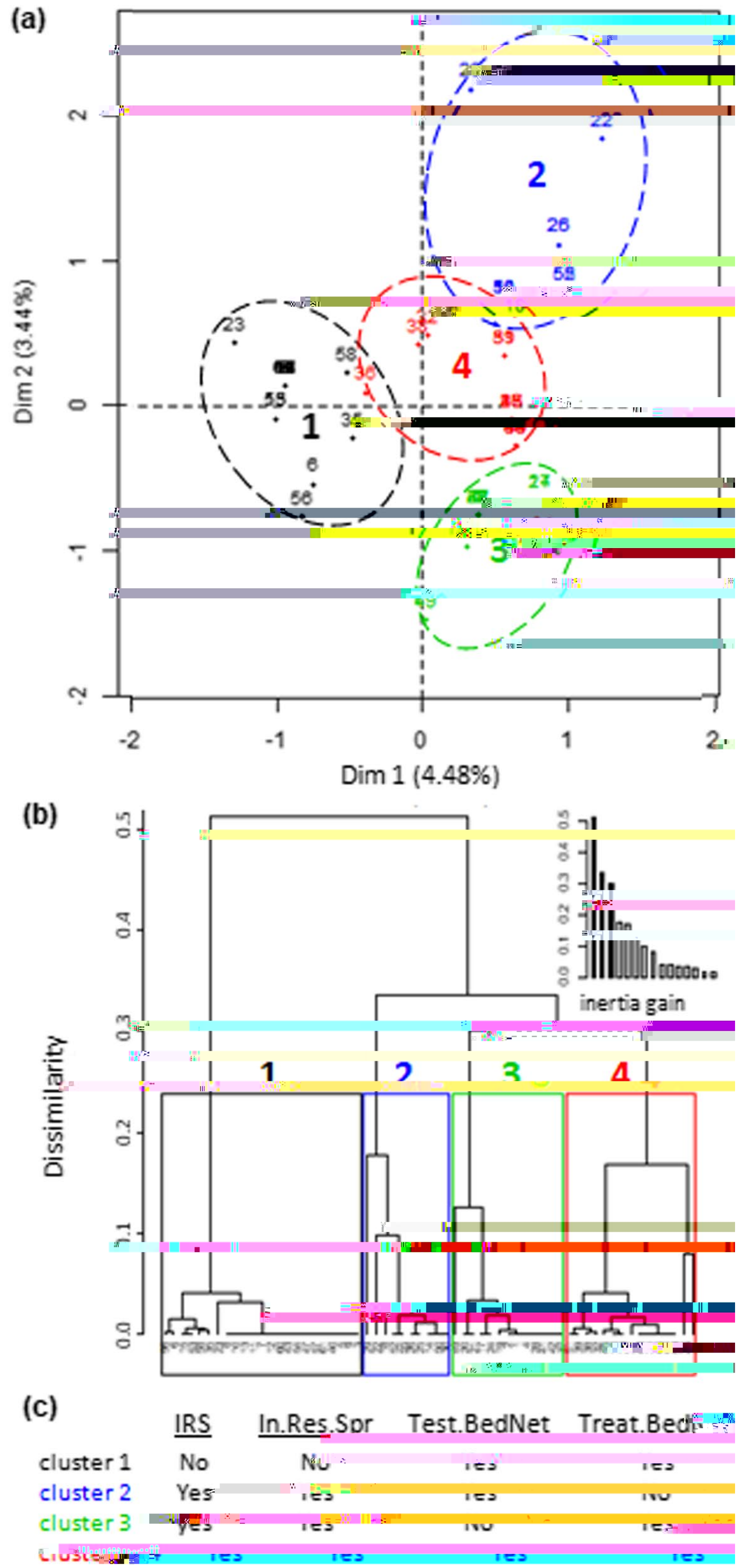

Fig. 6 A factor map (**a**) and a dendrogram (**b**) showing the four household groupings identified by passing on to HCPC out of the five (5) most significant MCA dimensions. Drivers of HCPC clustering in (**a**) as delineated by v-test values (Supplementary material appendix 1). Euclidean matrix was used

In detail, the present study shows that households without bed nets control malaria by applying IRS in combination with other preventive measures such as closing doors (with the hope of keeping mosquitos at bay), draining stagnant water pools where mosquitos lay their eggs, trimming mosquito covers around the homestead (grass) and/or receiving treatment after malaria episodes. An overall inclination towards using IRS against the spread of malaria was observed in the study area. 84% of households were found to be more likely to use IRS to control malaria vectors than the percentages of households in most countries in Africa [

Limitations

We acknowledge the limitations of the current study including the time constraints of conducting this research. We had limited time which significantly affected the geographical areas and the number of participants we could cover in depth. There was no qualitative study like a focus group interview which could offer insights into the sociocultural behaviours of people from northern Uganda that contribute to malaria remaining a problem in northern Uganda despite the many intervention efforts. Our questionnaire did not capture a couple of questions regarding the levels of education and socioeconomic data of households that are often linked to health outcomes, access to malaria information, acceptance to purchase of bednets and use of IRS and timely seeking of malaria treatment.

Conclusion

In this study, we show household predictors of episodes of malaria in northern Uganda to include: 1) the number of bed nets and sleeping in houses sprayed with insecticides; 2) the use of bed nets but no indoor residual spraying with insecticides and 3) the lack of use of bed nets at night and no indoor residual spraying. High episodes of malaria were correlated strongly, more so in children than in adults, with low usage of bed nets and a high number of individuals sleeping in the same household at night. These three clusters of households identified to exist in northern Uganda by studying the combinations of strategies used by households to contain malaria provides an opportunity to tailor-make preventive/intervention malaria messages to fit the individual household clusters.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-22175-8.

Supplementary Material 1.

Supplementary Material 2.

Supplementary Material 3.

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Authors' contributions

RE conceived, contributed design of the study, field collections, analyzed the data, and drafted an initial version of the manuscript. WSO and TI, performed field collections and analyzed the data, EAO and JJL conceived, designed the study, coordinated fieldwork and provided guidance, FA performed formal analysis, reviewed and edited the manuscript, OO carried out statistical analysis, reviewed and edited manuscript drafts. All authors read and approved the final manuscript.

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Data availability

The authors declare that all the main data supporting the findings of this study are available within the article (and its supplementary information files).

Declarations

Ethics approval and consent to participate

This study was approved by Gulu University Ethical Review Committee (GUREC13/11/2017). Formal approval to conduct the study was granted by the Uganda National Council for Science and Technology (UNCST) and the Office of the Ugandan President (SS4610). All methods were carried out in accordance with UNCST guidelines and regulations. Informed consent was taken from parents and guardians for participants below 16 years or in case they were illiterate. All the participants signed informed consent before participating in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Biology, Faculty of Science, Gulu University, P. O. Box 166,

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