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Exploring factors affecting malaria vaccination intention and COVID-19 vaccine uptake: evidence from a joint analysis in rural Senegal

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Abstract

Background Current malaria vaccination efforts target infants from 5 months of age; however, adult malaria mortality remains a significant and under-reported issue in high-transmission settings. Concerns are emerging that COVID-19-related vaccine hesitancy may extend to upcoming vaccines, including hypothetical ones such as a malaria vaccine for adults. This study investigates both shared and vaccine-specific determinants of malaria vaccination intention, comparing them with those influencing COVID-19 vaccine uptake.

Methods A cross-sectional telephone survey was conducted in 2023 among 795 adults residing in the rural area of Niakhar, Senegal. The Health Belief Model served as the analytical framework to identify determinants of vaccination behaviours and intentions. A multivariable bivariate probit model was used to jointly assess factors associated with favourable intentions to receive a hypothetical adult malaria vaccine and actual uptake of the COVID-19 vaccine.

Results Among surveyed participants, 35.6% had received at least one dose of a COVID-19 vaccine, and 58.6% expressed favourable intentions to receive a malaria vaccine, assuming it were available and free of charge. COVID-19-vaccinated individuals were 60% ($p < 0.001$) more likely to report favourable intentions to receive a malaria vaccine. In the multivariable probit model, perceived disease severity was more strongly associated with COVID-19 vaccine uptake, whereas perceived disease susceptibility more strongly predicted favourable intentions to receive a malaria vaccine. Women were more likely to support malaria vaccination ($p = 0.005$), while adults aged 59 years and older had higher rates of COVID-19 vaccination ($p < 0.001$).

Conclusions These findings suggest that although some determinants are vaccine-specific, most are shared across vaccines. The results offer actionable insights to guide future malaria vaccination strategies. Further research in urban settings and across diverse countries is warranted to enhance understanding of cross-vaccine perceptions and to inform targeted communication efforts.

Keywords Malaria, Malaria vaccine, COVID-19 vaccine, COVID-19, Vaccine hesitancy, Health Belief Model, Senegal, Public health

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Background

In 2021, 234 million cases of malaria were reported in the WHO African region, accounting for about 95% of cases and 96% of deaths globally [1]. On October 2, 2023, the World Health Organization (WHO) approved the R21/Matrix-M malaria vaccine, marking the second WHO-endorsed malaria vaccine after RTS,S/AS01, which was approved in 2021 [2]. Current malaria vaccination efforts target infants from 5 months of age, and seasonal malaria chemoprevention is recommended for children. Although malaria mortality is highest among children, evidence suggests a substantial and under-recognized burden in adults [3, 4]. The Million Death Study in India (2001–2003) estimated about 205,000 malaria deaths annually, nearly 60% of which occurred among adults aged 15–69 years [5]. Similarly, the INDEPTH Network analysis (2000–2012) across 49 African sites found a U-shaped mortality pattern, with deaths rising again in middle and older ages [6]. Census-based data have shown malaria to be a leading cause of death in Sierra Leone—responsible for 27% of all deaths in 2015 [7]—and in Mozambique (2007), where it accounted for 29% of all deaths, including 14% among those aged over 15 years [8]. These findings underscore that malaria morbidity and mortality in adults remain a significant concern in high-transmission settings and strengthen the rationale for considering adult malaria vaccination in the future.

Although adult malaria vaccination campaigns hold potential to reduce mortality and strengthen broader malaria control efforts [9, 10], they may also face considerable vaccine hesitancy (VH). In this regard, VH, defined as the delay in acceptance or refusal of vaccination despite availability [11]— was recognized as a major global health threat prior to the COVID-19 pandemic [12]. Concerns have emerged that COVID-19-related VH could extend to upcoming vaccines, including hypothetical ones such as a malaria vaccine for adults, thereby undermining their uptake [13, 14]. This concern is particularly relevant in sub-Saharan Africa (SSA), where COVID-19 VH has been particularly high, with hesitancy rates reaching up to 78% in Senegal and The Gambia in 2021–2022 [15, 16]. As a complex and context-dependent phenomenon, VH is shaped by factors that vary across time, settings, and vaccines [17, 18]. Some determinants—such as low confidence in vaccines in general or low trust in healthcare providers, institutions, and systems—are commonly associated with VH across multiple vaccines and diseases [19, 20]. Others— such as perceived sufficiency of vaccine-related knowledge or concerns about vaccine safety — may be vaccine-specific [21]. For example, studies on COVID-19 and influenza have shown that favourable attitudes toward vaccination in general, perceived benefits, and perceived susceptibility are shared determinants of hesitancy for both vaccines [21, 22]. However, COVID-19 VH appears to be more strongly influenced by safety concerns and lack of knowledge, whereas influenza VH is more closely associated with prior vaccination history [21]. Despite overlaps, important differences persist between general and vaccine-specific hesitancy, underscoring the need for tailored approaches to address VH effectively [23]. Although several scoping and systematic reviews [19, 20, 24] have investigated the determinants of VH across vaccine types, understanding the phenomenon remains challenging due to the complex interplay of multiple influencing factors. The heterogeneity of study contexts, populations, and methodologies often limits comparability and synthesis of findings, both for general and vaccine-specific determinants [19, 20].

In the context of malaria and COVID-19, fundamental differences exist between the two diseases. Malaria is long-standing and endemic in SSA, whereas COVID-19 emerged as an acute global pandemic. They differ in transmission modes, disease burden, public awareness, and the processes by which their vaccines were developed. As such, the determinants of VH are likely disease-specific, and hesitancy toward COVID-19 vaccines should not be assumed to directly influence the intention to receive a malaria vaccine. A nuanced understanding of both common and vaccine-specific factors is therefore essential to inform targeted strategies that promote vaccine acceptance—especially in SSA, where multiple infectious diseases coexist and immunization efforts often overlap.

This study aims to advance understanding of VH to the introduction of novel adult vaccines by identifying both common and vaccine-specific factors associated with malaria vaccination intention, in comparison with those influencing COVID-19 vaccine uptake. Specifically, we assessed both vaccines within the same population, with two primary objectives: (1) to evaluate intentions to receive a malaria vaccine, and (2) to identify key determinants of COVID-19 vaccine uptake and malaria vaccination intention to enable a comparative analysis. To achieve these objectives, we used data from the sixth wave (October–November 2023) of a longitudinal study initiated in July 2020 in rural Senegal, which accounts for about half of the country's population [25]. While the original aim of the study was to monitor individual intentions toward COVID-19 vaccination over time [26], its scope was later expanded to include attitudes toward malaria vaccination in wave 6. Investigating adult malaria vaccination was not intended to suggest immediate programmatic priority but rather to allow a consistent adult-to-adult comparison with COVID-19 vaccination behaviours.

At the time of data collection, Senegal had reported 89,022 confirmed COVID-19 cases and 1,971 deaths [27], with 15.2% of adults having received at least one vaccine dose [28]. Malaria incidence remained relatively low, averaging 48 cases per 1,000 individuals at risk during 2022–2023 [29], with an estimated 1,199,388 cases and 3,070 deaths in 2023 according the 2024 World Malaria Report by the WHO [30]. The country has a long-standing commitment to malaria control [31], exemplified by recent nationwide campaigns for the mass distribution of long-lasting insecticidal nets (LLINs) [32, 33]. Malaria drug-based prevention strategies primarily target children (seasonal malaria chemoprevention, SMC) and pregnant women (Intermittent preventive treatment in pregnancy, IPTp). However, no official announcement has yet been made regarding the integration of the malaria vaccine into Senegal's national Expanded Programme on Immunization (EPI).

Methods

Data collection and study population

Data were obtained from the CO3ELSER study, for which a detailed protocol has been described previously [26]. The study was conducted in the Niakhar area of the Fatick region, Senegal. Located 135 kms (km) southeast of Dakar and covering 203 km^2, the Niakhar area had a population of 50,355 inhabitants as of the January 2018 census. The main economic activities in the region include agriculture (primarily millet cultivation and peanut cash cropping) and small-scale cattle breeding. The CO3ELSER study was initially designed in 2020 as a three-wave longitudinal survey of 600 households and was subsequently extended with four additional waves in 2022–2024. The study employed a two-stage stratified sampling approach to select 600 households for participation. First, 12 villages (9 rural and 3 semi-urban) were randomly selected from the 30 villages in the Niakhar area. Then, 600 households were randomly chosen from the 1,756 households in these villages. In each selected household, both the head and the designated wife responsible for household management were interviewed. At baseline (wave 1, July 2020), 558 of the 600 households agreed to participate (response rate: 93.0%). The present analysis relies on data from the sixth wave, conducted between October and November 2023, in which 449 households (80.5%) participated. Households lost to follow-up were mainly unreachable or had moved out of the study area. Data collection was conducted via telephone interviews using VOXCO Mobile Offline v3 Computer-Assisted Telephone Interviewing (CATI) software between October 5 and November 29, 2023.

Outcomes

Surveyed participants were asked if they would be willing to receive a malaria vaccine, assuming it was available and free of charge, using a four-point Likert scale ("very unlikely"/"somewhat unlikely"/"somewhat likely"/"very likely" to get vaccinated). The first binary outcome was defined by categorizing participants who responded "very likely" as having a favourable intention to receive a malaria vaccine. The second binary outcome was defined by categorizing participants who reported being vaccinated for COVID-19 (i.e., having received at least one dose).

Covariates

The Health Belief Model (HBM) is one of the most widely used frameworks for understanding vaccination behaviour [34]. It conceptualizes vaccination decisions through the combination of key constructs, namely, perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy [35]. In this study, the HBM was employed as a framework to identify and compare the determinants of malaria vaccination intention and COVID-19 vaccine uptake. For both COVID-19 and malaria, participants' perceptions of susceptibility and severity were measured using Likert-type scales ranging from 0 (not at all) to 10 (extremely) [36]. Perceived benefits were assessed using a single item: participants' belief that the COVID-19 or malaria vaccine could prevent severe forms of the disease. Perceived barriers included concerns about purchasing counterfeit medication and general VH, reflecting a broad reluctance toward all vaccines. Distance to the nearest health post was also included. Because this last variable was highly skewed and exploratory analyses suggested non-linear associations, we dichotomized this variable at the median (into $\leq$ or $>$ 2 km) to ensure robustness and interpretability. Cues to action were measured by self-reported positive COVID-19 or malaria status for the participant or a household member. Behavioural practices reflecting individuals' self-efficacy in preventing malaria or COVID-19 were also collected. These included adherence to preventive measures for COVID-19 (e.g., hand hygiene, mask-wearing, physical distancing) and regular use of LLINs (insecticide-impregnated bed nets designed for malaria prevention). According to the HBM, modifying factors—such as socio-demographic and socio-economic characteristics—may indirectly influence vaccination decisions by shaping individuals' perceptions of disease severity, susceptibility, benefits, and barriers [37]. We therefore included the following variables as modifying factors in the model: age, gender, education level, perceived health status (measured on an eleven-point Likert scale from "very poor" [0] to "very good"), place of residence (rural or semi-urban), and household wealth index. The household wealth index was constructed as a composite measure using principal component analysis (PCA), in line with the methodology used in the Demographic and Health Surveys (DHSs) [38]. This index accounted for factors such as access to sanitation facilities, electricity, and ownership of household items (e.g., television, computer, refrigerator). Ten items were included in the wealth index, with a Cronbach's α = 0.70 (see Additional File 1). For regression analyses, the wealth index was standardized (z-scores with mean = 0 and standard deviation = 1) to facilitate interpretation and comparability of coefficients.

Statistical analysis

For bivariate analyses, categorical variables were compared using Fisher's exact test, and continuous variables were compared using the Mann–Whitney U test. This approach was chosen because some continuous variables (e.g., distance to the nearest health post, perceived health status) were not normally distributed, and to maintain consistency by applying non-parametric tests across all bivariate comparisons. For multivariable analysis, this study aimed to simultaneously identify and compare the factors influencing both COVID-19 vaccine uptake and malaria vaccination intention. Analysing these two outcomes separately could lead to biased parameter estimates if the error terms are correlated [39]. To account for this potential correlation, we used a bivariate probit model, which jointly estimates both equations and captures the correlation between the unobserved components of the two outcomes. The generic form of the bivariate probit model is as follows [40]:

$$Z_{1i}^{*} = x_{1i}\beta_{1i} + e_{1i}$$

$$Z_{1i} = \begin{cases} 1, if Z_{1i}^{*} > 0 \\ 0, otherwise \end{cases}$$

$$Z_{2i}^{*} = x_{2i}\beta_{2i} + e_{2i}$$

$$Z_{2i} = \begin{cases} 1, if Z_{2i}^{*} > 0 \\ 0, otherwise \end{cases}$$

Z_1 is the observed COVID-19 vaccine uptake variable, x_1 is the vector of independent variables, β_1 is a vector of parameters to be estimated, and e_1 is a random error term. Z_2 is the observed malaria vaccination intention variable, x_2 is the vector of independent variables, β_2 is a vector of parameters to be estimated, and e_2 is a random error term.

The error terms e_1 and e_2 are assumed to follow a bivariate normal distribution with zero mean, unit variance, and correlation ρ.

To estimate the magnitude of the effects of the covariates on each outcome, we computed marginal effects (ME). ME represent the change in the probability of the outcome associated with a one-unit change in the explanatory variable, holding all other variables constant. ME provide a more intuitive measure of effect size than raw regression coefficients. Multicollinearity was assessed using the variance inflation factor (VIF). All analyses were based on two-sided p-values, with statistical significance defined as p ≤ 0.05. Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

Results

A total of 795 individuals participated in the survey, including 449 heads of households and 346 spouses. The mean age of participants was 50.8 ± 12.6 years, and 73.6% had no formal education. The majority were engaged in farming (60.6%), while 17.9% worked in crafts and 15.0% in blue-collar occupations (Table 1). Overall, 35.6% of participants reported having received at least one dose of a COVID-19 vaccine, and 58.6% stated they would be "very likely" to get vaccinated if a malaria vaccine were available and free of charge for adults (Fig. 1). Cross-tabulation analysis indicated that participants who reported COVID-19 vaccination were 60% more likely to express favourable intentions to receive a malaria vaccine (crude Relative Risk = 1.60; 95% Confidence Interval: 1.43–1.79; $p < 0.001$).

In bivariate associations (Table 1), several Health HBM constructs—including perceived susceptibility, severity, benefits, barriers, and behavioural practices—were similarly associated with COVID-19 vaccine uptake and favourable intentions to receive a malaria vaccine. However, some modifying factors, such as age and gender, showed contrasting associations with the two outcomes. Favourable intentions to receive a malaria vaccine were somewhat higher among younger participants aged 18–39 years (66.2%, $p = 0.042$) and among women (65.0%, $p = 0.001$), whereas COVID-19 vaccine uptake was markedly higher among older participants aged > 59 years (44.5%, $p < 0.001$), with no significant gender difference observed for this outcome ($p = 0.765$).

In the multivariable analyses (Table 2), the use of a bivariate probit model was justified by a statistically significant disturbance correlation parameter (ρ = 0.19, $p = 0.013$). These results suggest that unobserved factors jointly influenced both outcomes, supporting the appropriateness of simultaneous modelling rather than separate regressions. Compared to the standard probit model, the bivariate probit model yielded attenuated effect sizes, indicating that accounting for correlation between the two outcomes reduced the estimated magnitudes of associations. However, the overall results remained qualitatively consistent across both modelling approaches. No major multicollinearity issues were detected, as all VIF values were below 3 in both models. Several factors influenced both outcomes in similar ways (Table 3). In particular, general hesitancy toward vaccination emerged as the strongest negative predictor of COVID-19 vaccine uptake (ME = –0.51, $p < 0.001$), and

Table 1 Population characteristics and bivariate associations with COVID-19 vaccine uptake and malaria vaccination intention (*n* = 795)

	COVID-19 Vaccination status				**Malaria vaccination intention**				**All (*n* = 795)**	
	Not vaccinated *n* = 512 (64.4%)		**Vaccinated *n* = 283 (35.6%)**		**Not favourable *n* = 329 (41.4%)**		**Favourable *n* = 466 (58.6%)**			
	n†	**%†**	**n†**	**%†§**	**n†**	**%†**	**n†**	**%†**	**n†**	**%†**
Age—mean(std)	49.2(12.3)		53.7(12.6)***		51.4(12.2)		50.3(12.9)		50.8 (12.6)	
18–39	118	78.2	33	21.9***	51	33.8	100	66.2*	151	19.0
40–59	273	64.1	153	35.9	192	45.1	234	54.9	426	53.6
> 59	121	55.5	97	44.5	86	39.5	132	60.6	218	27.4
Gender										
Women	225	65.0	121	35.0	121	35.0	225	65.0**	346	43.5
Men	287	63.9	162	36.1	208	46.3	241	53.7	449	56.5
Education										
No formal education	386	66.0	199	34.0	249	42.6	336	57.4*	585	73.6
Primary education	80	61.5	50	38.5	58	44.6	72	55.4	130	16.4
Secondary education	46	57.5	34	42.5	22	27.5	58	72.5	80	10.1
Occupation										
Farmer	303	62.9	179	37.1	206	42.7	276	57.3	482	60.6
Craftsperson	95	66.9	47	33.1	53	37.3	89	62.7	142	17.9
Intermediate/Managerial	11	68.8	5	31.3	7	43.8	9	56.3	16	2.0
Employee/blue-collar worker	79	66.4	40	33.6	49	41.2	70	58.8	119	15.0
Inactive	24	66.7	12	33.3	14	38.9	22	61.1	36	4.5
Place of residence										
Rural	210	65.8	109	34.2	124	38.9	195	61.1	319	40.1
Semi-urban	302	63.5	174	36.6	205	43.1	271	56.9	476	59.9
Household wealth index—mean(std)	−0.1(0.9)		0.2(1.1)**		−0.2(0.8)		0.1(1.1)***		0.0(1.0)	
Perceived health status (0–10 scale)—mean(std)	7.9(2.9)		8.6(1.9)*		7.8(2.9)		8.4(2.3)**		8.2 (2.6)	
COVID-19/malaria perceived susceptibility (0–10 scale)										
COVID-19—mean(std)	0.8(1.3)		1.2(1.4)***		0.7(1.1)		1.0(1.5)*		0.9(1.4)	
Malaria—mean(std)	2.7(1.6)		2.7(1.6)		2.4(1.3)		2.9(1.7)***		2.7(1.6)	
COVID-19/malaria perceived severity (0–10 scale)										
COVID-19—mean(std)	2.9(2.9)		4.1(3.1)***		2.9(2.8)		3.7(3.1)***		3.3 (3.0)	
Malaria—mean(std)	4.4(2.9)		4.8(3.1)		4.2(2.9)		4.8(3.1)**		4.5 (3.0)	
Cues to action										
At least one family member got infected with COVID-19										
No	485	66.2	248	33.8***	318	43.4	415	56.6***	733	92.2
Yes	27	43.6	35	56.5	11	17.7	51	82.3	62	7.8
Remembers having had malaria at least once										
No	281	62.2	171	37.8	177	39.2	275	60.8	452	56.9
Yes	231	67.4	112	32.7	152	44.3	191	55.7	343	43.1
Perceived barriers										
Fear of buying counterfeit medication										
Never/Sometimes	370	66.2	189	33.8	208	37.2	351	62.8***	559	70.3
Always/Often	142	60.2	94	39.8	121	51.3	115	48.7	236	29.7
Generally hesitant to get vaccinated										
No, not at all	452	61.6	282	38.4***	291	39.7	443	60.4***	734	92.3
Rather not/Yes, rather/Yes, absolutely	60	98.4	1	1.6	38	62.3	23	37.7	61	7.7
Distance to the nearest health post (km)										
≤ 2 km	317	65.1	170	34.9	188	38.6	299	61.4*	487	61.3
> 2 km	195	63.3	113	36.7	141	45.8	167	54.2	308	38.7
Perceived benefits										
The COVID-19 vaccine prevents severe forms of the disease										
Don't agree	245	96.5	9	3.5***	175	68.9	79	31.1***	254	32.0
Agree	267	49.4	274	50.7	154	28.5	387	71.5	541	68.1

Table 1 (continued)

	COVID-19 Vaccination status				Malaria vaccination intention				All ($n=795$)	
	Not vaccinated $n=512$ (64.4%)		Vaccinated $n=283$ (35.6%)		Not favourable $n=329$ (41.4%)		Favourable $n=466$ (58.6%)			
	n†	%†	n†	%†5	n†	%†	n†	%†	n†	%†
Would like to get vaccinated for malaria to prevent severe forms of the disease										
Don't agree	132	84.6	24	15.4***	138	88.5	18	11.5***	156	19.6
Agree	380	59.5	259	40.5	191	29.9	448	70.1	639	80.4
Behavioural practices										
It is important to follow preventive measures (hand hygiene, wearing masks, physical distancing) to protect those who are not vaccinated										
Don't agree	145	94.8	8	5.2***	119	77.8	34	22.2***	153	19.3
Agree	367	57.2	275	42.8	210	32.7	432	67.3	642	80.8
Use of long-lasting insecticide-treated nets										
No/Sometimes	104	75.4	34	24.6**	79	57.3	59	42.8***	138	17.4
During the rainy season/Every night	408	62.1	249	37.9	250	38.1	407	62.0	657	82.6
Use of mosquito repellent sprays										
No	188	60.5	123	39.6	123	39.6	188	60.5	311	39.1
Sometimes/Often	324	66.9	160	33.1	206	42.6	278	57.4	484	60.9

†mean(std) for continuous variables

*, **, ***: $p<0.05$, $p<0.01$ and $p<0.001$ respectively. Fisher's exact test for categorical variables and Mann–Whitney U test for continuous variables

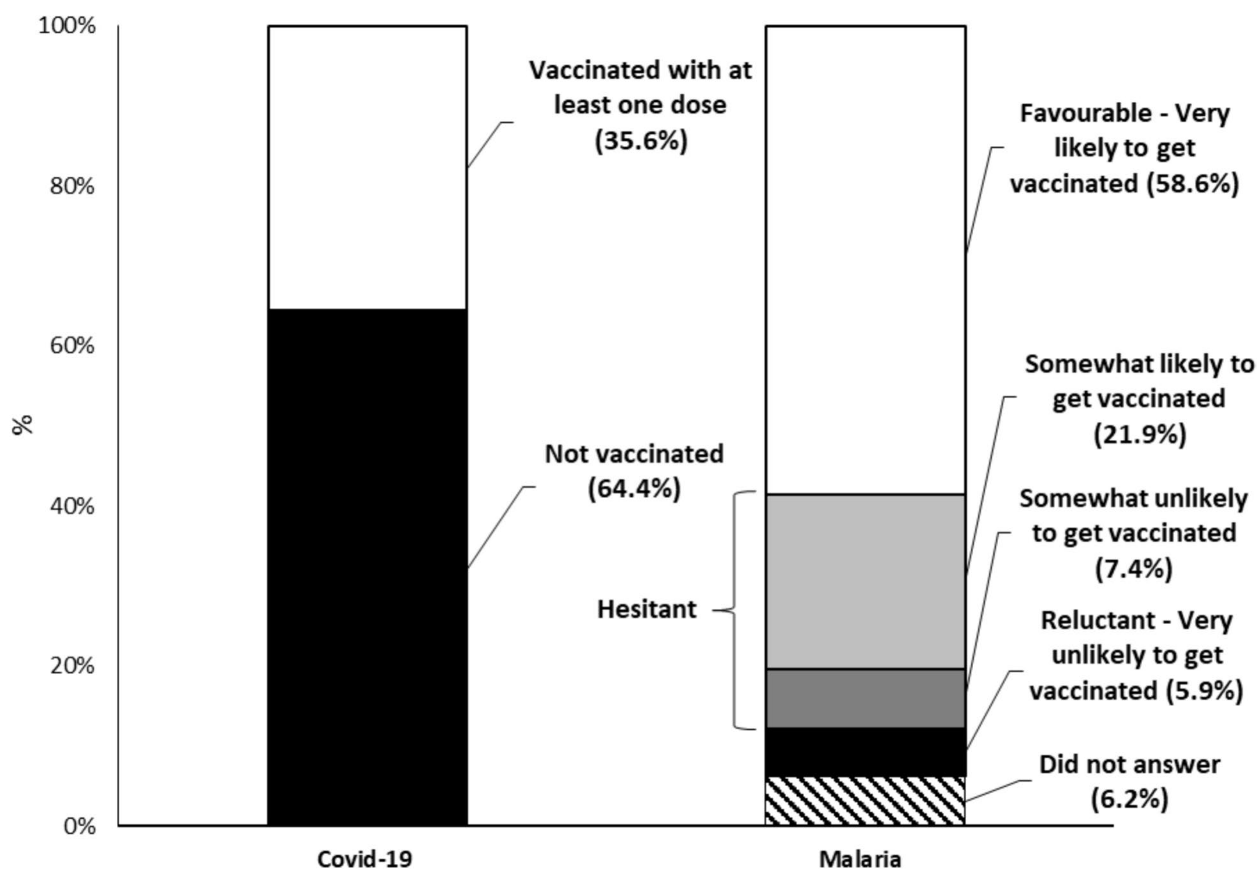

Fig. 1 COVID-19 vaccine uptake and malaria vaccination intention ($n=795$). Cross-tabulation analysis indicated that participants who reported COVID-19 vaccination were 60% more likely to express favourable intentions to receive a malaria vaccine (RR = 1.60; 95% CI: 1.43–1.79; $p<0.001$)

Table 2 Multivariable standard and bivariate probit model estimates of factors associated with COVID-19 vaccine uptake and favourable malaria vaccination intention ($n = 795$)

	COVID-19				Malaria			
	Standard probit estimates		Bivariate probit estimates		Standard probit estimates		Bivariate probit estimates	
	β	*p*-value	β	*p*-value	β	*p*-value	β	*p*-value
Disease perceived susceptibility†	0.01	0.885	0.00	0.984	0.25	< 0.001	0.25	< 0.001
Disease perceived severity†	0.15	0.008	0.15	0.007	–0.12	0.057	–0.11	0.070
Cues to action								
At least one family member got infected with COVID-19	0.41	0.041	0.37	0.059				
Remembers having had malaria at least once					–0.22	0.052	–0.22	0.051
Perceived barriers								
Fear of buying counterfeit medication (Always/Often)	0.22	0.090	0.23	0.071	–0.26	0.035	–0.27	0.031
Generally hesitant to get vaccinated (Rather not/Yes, rather /Yes, absolutely)	–1.91	<.0001	–1.94	<.0001	–0.43	0.037	–0.44	0.034
Distance to the nearest health post > 2 km	0.30	0.009	0.29	0.014	–0.22	0.045	–0.22	0.044
Perceived benefits								
The COVID-19 vaccine prevents severe forms of the disease	1.71	<.0001	1.66	<.0001				
Would like to get vaccinated for malaria to prevent severe forms of the disease					1.70	<.0001	1.65	<.0001
Behavioural practices								
It is important to follow preventive measures (hand hygiene, wearing masks, physical distancing) to protect those who are not vaccinated (Agree)	0.35	0.170	0.31	0.211				
Use of long-lasting insecticide-treated nets					0.58	<.0001	0.58	<.0001
Other covariates								
Age (Ref. 18–39)								
40–59	0.60	< 0.001	0.61	<.0001	–0.14	0.328	–0.14	0.326
> *59*	0.97	<.0001	0.99	<.0001	0.18	0.304	0.17	0.322
Gender (ref. Men)								
Women	0.12	0.319	0.14	0.262	0.35	0.005	0.34	0.005
Education (ref. No formal education)								
Primary Education	0.14	0.359	0.13	0.365	–0.11	0.425	–0.11	0.434
Secondary Education	0.14	0.458	0.17	0.380	0.25	0.199	0.26	0.180
Place of residence (ref. Rural)								
Semi-urban	0.21	0.068	0.21	0.065	–0.14	0.183	–0.13	0.204
Household wealth index†	0.15	0.008	0.15	0.006	0.17	0.005	0.17	0.005
Perceived health status †	0.02	0.767	0.04	0.577	0.23	<.0001	0.23	<.0001
Disturbance correlation ρ			0.19	0.013				

†Continuous variables were standardized to z-scores prior to multivariable regression analysis

it was also significantly, though less strongly, negatively associated with favourable intentions to receive malaria vaccine (ME = –0.12, $p = 0.034$). Similarly, perceived benefits—especially the belief that vaccines prevent severe forms of a disease—were positively associated with both outcomes, with marginal effects of + 0.44 for COVID-19 and + 0.47 for malaria ($p < 0.001$ for both). Additionally, household wealth was modestly but positively associated with both outcomes (ME = + 0.04 for COVID-19; ME = + 0.05 for malaria). While perceived disease severity and susceptibility appeared to influence both vaccines similarly in the bivariate analyses (Table 1), the multivariable model revealed important distinctions. Greater perceived severity of disease was a stronger predictor of COVID-19 vaccine uptake (ME = + 0.04, $p = 0.007$), whereas higher perceived susceptibility was more strongly associated with favourable intentions to receive a malaria vaccine (ME = + 0.07, $p < 0.001$). Other factors were uniquely associated with only one outcome. In terms of sociodemographic characteristics, the multivariable model showed that older adults (>59 years) were significantly more likely to report being vaccinated against COVID-19 (ME = + 0.26, $p < 0.001$), whereas age had no significant effect on malaria vaccination intention ($p = 0.322$). By contrast, women were more likely than men to express favourable intentions to receive a malaria vaccine (ME = + 0.10, $p = 0.005$), while gender showed no significant association with COVID-19 vaccine uptake ($p = 0.262$). Associations with behavioural practices also differed by outcome. Adherence to preventive measures

Table 3 Marginal effects from the multivariable bivariate probit model for factors associated with COVID-19 vaccine uptake and favourable malaria vaccination intention ($n = 795$)

	COVID-19		Malaria	
	Marginal effect†	p-value	Marginal effect†	p-value
Disease perceived susceptibility‡	+0.00	0.984	+0.07	< 0.001
Disease perceived severity‡	+0.04	0.007	–0.03	0.070
Cues to action				
At least one family member got infected with COVID-19	+0.10	0.059		
Remembers having had malaria at least once			–0.06	0.051
Perceived barriers				
Fear of buying counterfeit medication (Always/Often)	+0.06	0.071	–0.08	0.031
Generally hesitant to get vaccinated (Rather not/Yes, rather/Yes, absolutely)	–0.51	<.0001	–0.12	0.034
Distance to the nearest health post > 2 km	+0.08	0.014	–0.06	0.044
Perceived benefits				
The COVID-19 vaccine prevents severe forms of the disease	+0.44	<.0001		
Would like to get vaccinated for malaria to prevent severe forms of the disease			+0.47	<.0001
Behavioural practices				
It is important to follow preventive measures (hand hygiene, wearing masks, physical distancing) to protect those who are not vaccinated (Agree)	+0.08	0.211		
Use of long-lasting insecticide-treated nets			+0.16	<.0001
Other covariates				
Age (Ref. 18–39)				
40–59	+0.16	<.0001	–0.04	0.326
> 59	+0.26	<.0001	+0.05	0.322
Gender (ref. Men)				
Women	+0.04	0.262	+0.10	0.005
Education (ref. No formal education)				
Primary Education	+0.04	0.365	–0.03	0.434
Secondary Education	+0.04	0.380	+0.07	0.180
Place of residence (ref. Rural)				
Semi-urban	+0.05	0.065	–0.04	0.204
Household wealth index‡	+0.04	0.006	+0.05	0.005
Perceived health status‡	+0.01	0.577	+0.06	<.0001

†For continuous variables, marginal effects represent the change in the probability of the outcome associated with a one standard deviation increase in the variable. For categorical variables, marginal effects represent the discrete change in the probability of the outcome when moving from the reference category to the indicated category

‡Continuous variables were standardized to z-scores prior to multivariable regression analysis

for COVID-19—including hand hygiene, mask-wearing, and physical distancing—was not significantly associated with COVID-19 vaccination ($p = 0.211$), whereas regular use of LLINs was positively associated with favourable intentions to receive a malaria vaccine (ME = +0.16, $p < 0.001$). Finally, better perceived health status was positively associated with favourable intentions to receive a malaria vaccine (ME = +0.06, $p < 0.001$).

Discussion

Although previous studies have compared intentions regarding COVID-19 vaccination with those for other vaccines [20, 22, 24], this is, to our knowledge, the first study in SSA to jointly examine the determinants of COVID-19 vaccine uptake and intentions to receive a malaria vaccine within the same population. Although the malaria vaccination scenario was hypothetical, we identified several determinants that were also significantly associated with actual COVID-19 vaccine uptake. This parallel analysis offers novel insights into both common and vaccine-specific drivers of VH. Importantly, our findings suggest that key constructs such as perceived susceptibility and severity, perceived benefits of vaccination, and general VH operate across both vaccine contexts, underscoring their relevance for future immunisation strategies. At the same time, vaccine-specific differences emerged: older age was uniquely associated with COVID-19 vaccine uptake, whereas being a woman and regular use of LLINs were more strongly associated with favourable intentions to receive a malaria vaccine. These differences highlight the need to tailor communication and engagement strategies to the specific features and target populations of each vaccine. Overall, these findings provide valuable evidence to inform future research and support the design of effective adult malaria vaccination programs in the region.

Common determinants of COVID-19 and malaria vaccine acceptance

Perceived disease risk emerged as a key common determinant of both COVID-19 vaccine uptake and favourable intentions to receive a malaria vaccine. However, the relative contributions of perceived susceptibility and perceived severity differed depending on the disease: perceived severity was a stronger predictor of COVID-19 vaccine uptake, whereas perceived susceptibility was the stronger predictor of malaria vaccination intention. For COVID-19, factors such as the disease's novelty, widespread media coverage, and public health messaging emphasizing severe outcomes may have heightened perceptions of severity, even among individuals who did not consider themselves personally at high risk of infection [41, 42]. As a result, perceived severity likely played a key role in decisions to receive the COVID-19 vaccine. This finding is somewhat unexpected, as a systematic review of studies using the HBM identified perceived susceptibility as a more consistent predictor of COVID-19 VH than perceived severity [34]. In contrast, malaria's endemic presence in Senegal may have led to a heightened perception of susceptibility [43, 44]. Given that malaria is a well-known and recurring illness, its threat may have been normalized, prompting individuals to focus more on the likelihood of infection than on its potential severity.

Another important finding of this study is that perceived benefits and barriers played a significant role in shaping behaviours and intentions toward both vaccines, consistent with previous studies on COVID-19 and influenza that have also identified these factors as common determinants of VH [21, 22]. The comparable impact of perceived barriers on both vaccines may stem from shared underlying determinants of VH [45]. People who are generally hesitant about vaccines often share deep-rooted concerns regarding vaccine safety, efficacy, or trust in health authorities—concerns that extend across all vaccines, including those for COVID-19 and malaria [45, 46]. Similarly, the perceived benefits of vaccination emerged as a crucial factor for both vaccines, suggesting that public health messaging emphasising the protective effects of vaccines could serve as a unified strategy to improve vaccine acceptance across various diseases. This aligns with previous research highlighting the importance of perceived effectiveness in vaccine decision-making [47, 48]. The significant influence of perceived barriers and benefits on vaccination behaviours and intentions is an expected finding—particularly for COVID-19—as systematic reviews have identified these constructs as the most commonly associated with COVID-19 VH [49–51].

Specific determinants of COVID-19 and malaria vaccine acceptance

Our study also identified specific factors, notably age and gender, that exert differentiated effects on COVID-19 vaccine uptake and malaria vaccination intention. As demonstrated in this study and supported by systematic reviews and meta-analyses [49–51], COVID-19 vaccine uptake was significantly higher among older adults. This trend may be explained by older individuals perceiving a greater risk of severe outcomes from COVID-19, making them more likely to prioritize vaccination. Additionally, older adults were among the primary target groups for COVID-19 vaccination campaigns, further increasing their likelihood of vaccine acceptance. In contrast, younger adults showed a tendency toward more favourable intentions to receive a malaria vaccine—possibly reflecting a heightened perceived susceptibility to malaria as an endemic threat—although this association was not statistically significant after adjustment. Similar findings have been reported in studies from Kenya [52] and Ethiopia [53], suggesting that younger adults' greater perceived vulnerability to malaria may contribute to their more favourable intentions to receive a vaccine. The significantly higher rate of favourable intentions to receive a malaria vaccine observed among women may reflect their central roles in household health decision-making. Women, particularly mothers, often serve as the primary decision-makers regarding their children's health, including vaccination choices [54]. Additionally, pregnant women are frequently targeted by malaria prevention strategies, such as intermittent preventive treatment during pregnancy, which is recommended to reduce the burden of malaria in endemic regions. This targeted focus likely enhances women's awareness of malaria risks and fosters greater acceptance of preventive measures, including vaccination. Conversely, although many studies have reported lower COVID-19 vaccine uptake among men [49–51], our study did not observe any significant difference in vaccine uptake likelihood between men and women. While age and gender appear to influence malaria and COVID-19 vaccination in different ways, comparisons between the two should be made with caution. In particular, women's greater support for malaria vaccination could relate not only to their involvement in pregnancy-related strategies but also to their central role in household health decisions [55]. By contrast, COVID-19 vaccination behaviours have been shown to be complex and context-dependent, shaped by multiple sociodemographic and behavioural factors [56].

Limitations

This study is limited to the Niakhar area in rural Senegal, and the findings may not be generalisable to other regions with different cultural or epidemiological contexts. Moreover, the evolving nature of the COVID-19 pandemic and ongoing developments in malaria vaccination may further limit the generalisability of our findings. While our measure of perceived barriers includes factors such as concerns about counterfeit medication and healthcare accessibility, it lacks vaccine- or disease-specific variables. Future research should incorporate factors such as concerns about vaccine safety and the perceived severity of side effects, which are more directly related to the characteristics of the targeted vaccine and disease context. As data were collected through a cross-sectional telephone survey, interviewer bias cannot be fully excluded. Although interviewers were trained to follow a standardised protocol, variations in tone, probing, or clarification during calls may have influenced participants' responses. Another limitation is related to attrition: although participation remained relatively high (80.5% of baseline households), those lost to follow-up tended to have a lower household wealth index. This difference may have introduced a selection bias, and results should therefore be interpreted with some caution. Finally, although studies have shown that vaccine intentions strongly predict actual vaccine uptake [57–60], decision-making processes differ when considering a hypothetical vaccine, such as a malaria vaccine for adults, versus making a real-world decision about an available vaccine, like the COVID-19 vaccine. Therefore, comparisons between vaccine intentions and actual uptake should be made with caution, especially when contrasting hypothetical vaccination scenarios with real-world decisions.

Conclusions

Overall, our findings provide valuable evidence to inform future research and support the design of effective adult malaria vaccination programmes in the region. In particular, our results underscore the importance of education and community outreach to increase awareness of adult malaria risk, inform populations about the benefits of vaccination, and foster open dialogue that builds trust in new immunisation strategies. Importantly, we also identified specific subgroups—such as men for malaria vaccination and younger adults for COVID-19 vaccination—that may particularly benefit from targeted outreach efforts. Focusing education and engagement strategies on these groups could help mitigate VH among those most at risk. Further research exploring malaria vaccination intentions in urban settings and across diverse SSA countries would offer important comparative perspectives. As malaria vaccines become more widely available, longitudinal studies assessing real-world acceptance and uptake will be essential to guide and adapt vaccination strategies over time.

Abbreviations

SSA	Sub-Saharan Africa
WHO	World Health Organization
VH	Vaccine Hesitancy
EPI	Expanded Programme on Immunization
HBM	Health Belief Model
CATI	Computer-Assisted Telephone Interviewing
LLINs	Long-Lasting Insecticidal Nets
VIF	Variance Inflation Factor
RR	Relative Risk
CI	Confidence Interval
DHS	Demographic and Health Survey
Km	Kilometre

Supplementary Information

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Additional file 1. Factor loadings of variables used in the construction of the household wealth index. This file presents the list of items used to construct the household wealth index, along with their coordinates on the first axis of the factor analysis.

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Conceptualization: S.C, V.S and C.S; Formal analysis: S.C and V.S; Investigation (data collection): G.M, E–H.B and C.S; Writing—Original Draft: S.C and V.S. Writing—Reviewing and Editing: All authors. Supervision, Project administration and Funding acquisition: V.S and C.S.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study involved human participants and was approved by the Senegalese National Ethical Committee for Research in Health (131/MSAS/CNERS/Sec and 218/MSAS/CNERS/SP), Senegalese Ministry of Health (619/MSAS/DPRS/DR) and French Data Protection Authority (CNIL 2220771v0). All participants provided consent prior to participation. More specifically, consent was first recorded when community health workers (Badienou Gokh) visited selected households to inform households' members about the study and collect telephone numbers of members who agreed to participate. At the beginning of the first survey, the study purpose was explained and the participants were asked again to provide verbal consent to participate. As a way of thanking households for their participation, the community health workers provided them with a personal protection kit including hydroalcoholic gel and a face mask at the end of the first wave of data collection. All procedures were carried out in accordance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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