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Investigating Non-Compliance with COVID-19 Vaccination through Hesitancy, Refusal, and Access Limitation: A Community-Based Survey from the Democratic Republic of the Congo

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Abstract

Introduction: Vaccination plays a pivotal role in mitigating the repercussions of the COVID-19 pandemic. However, vaccination campaigns encounter obstacles, especially in developing countries like the Democratic Republic of the Congo (DRC). This study aimed at investigating the roles of vaccine hesitancy, refusal, and access barriers, while identifying individual-level factors associated with non-vaccination in Mbujimayi, DRC. **Methods:** A community-based cross-sectional survey was conducted in three health districts and included 1496 residents. Attitudes and behaviors related to seeking COVID-19 vaccination were assessed using a standardized questionnaire. Hierarchical logistic regression modeling was used to assess factors potentially affecting non-compliance with vaccination. **Results:** Among participants (median age = 33, IQR = 23.3, M/F sex ratio = 0.7), 60% displayed misconceptions about COVID-19 or its vaccine, while only 35.2% perceived COVID-19 as a significant health threat. Vaccination coverage was estimated at 49.1% (95% CI: 47.5; 52.6), with 71.8% of vaccinated individuals having received one dose. Among the unvaccinated individuals, 50.9% expressed no intention to be vaccinated in the future, citing hesitation (30.4%) or refusal (39.6%) mainly due to side effects or distrust of

vaccines. Conversely, 32.7% of the unvaccinated persons expressed access barriers despite willingness to be vaccinated. Misconceptions about COVID-19 and its vaccines were the main drivers of vaccination non-compliance. **Conclusion:** These findings demonstrate significant vaccine non-compliance driven by hesitancy, refusal, and access barriers. Strategies to enhance vaccination coverage and pandemic preparedness should address misconceptions, sociodemographic barriers, and geographic disparities.

Keywords

COVID-19, Vaccination, Non-Observance, Community, Democratic Republic of the Congo

1. Introduction

The global crisis instigated by the emergence and spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) led to the Coronavirus Disease 2019 (COVID-19) pandemic [1]. Vaccines have shown a pivotal role in countering this crisis, significantly impacting infection prevention, disease severity reduction, and the preservation of countless lives [2]. The rapid development and deployment of vaccines represented a remarkable scientific achievement, catalyzing a collaborative and urgent response to combat the challenges posed by the novel virus [3]. COVID-19 vaccination has not only demonstrated effectiveness in protecting individuals, but also has played a crucial role in establishing community-level immunity, subsequently disrupting the transmission of the virus and containing its spread [4] [5].

However, during the global effort to vaccinate against SARS-CoV-2, Africa encountered significant challenges in achieving widespread vaccine uptake [6]. Several African regions maintained suboptimal vaccination rates, posing significant health risks throughout the pandemic. As of June 2023, the World Health Organization (WHO) African Region reported the lowest vaccination coverage at 33%, compared to 64% globally [7] [8]. Despite efforts to address disparities, vaccination coverage varied widely among African countries [9] [10]. Within populations, vaccine hesitancy, refusal, and access barriers could have posed unique challenges to vaccination [11]. While vaccine hesitancy is a relatively novel concept, recent research suggests that it is not necessarily reflected in behavior—or whether or not an individual has been vaccinated—but rather as a psychological disposition [12]. Understanding the nuances between vaccine hesitancy, refusal, and access barriers is crucial, as they can differently be influenced by factors such as misinformation, socioeconomic disparities, and healthcare infrastructure challenges [13]-[16]. The mechanisms driving vaccine uptake across Africa's diverse landscapes remain poorly understood, necessitating comprehensive investigations into vaccine-seeking behaviors [17] [18]. Exploring these dynamics could inform strategies for combating future pandemics and other preventable

diseases.

The Democratic Republic of the Congo (DRC) stands among the African nations with notably low COVID-19 vaccination coverage [9]. Delays in vaccine planning and deployment across the country may have contributed to this scenario, as mass vaccination campaigns commenced only in April 2021, initially only in Kinshasa, the capital city [14]. Subsequent efforts saw the establishment of vaccination sites across other provinces from July 2021 [14]. However, the DRC encountered various challenges in vaccine rollout, including limited vaccine supply, distribution infrastructure, and population hesitancy [14] [17] [19]. Despite vaccines being available to the public, logistical constraints hindered the Congolese population from receiving millions of intended vaccine doses [14]. Consequently, the country fell short of vaccination targets, making it a crucial case study for understanding vaccine hesitancy, refusal, and access challenges [9]. By May 31st, 2023, only 18.2% of the population had been vaccinated [20]. Situated within the complex socioeconomic, cultural, and health milieu of Central Africa, the DRC presents a diverse landscape characterized by varied ethnicities, languages, and regional disparities [21]. Previous research has highlighted factors such as economic status and awareness of COVID-19 existence as determinants of vaccine acceptance [22]. Therefore, exploring local-level factors influencing public attitudes toward COVID-19 vaccination is imperative for promoting effective vaccine uptake and preparedness for future preventable outbreaks [14] [15].

This study was conducted to assess local vaccination coverage and explore factors influencing COVID-19 vaccine-seeking behaviors from an individual's perspective. Attitudes and practices related to COVID-19 vaccines were analyzed to elucidate vaccine hesitancy, refusal, and access barriers at the community level. The study identified factors associated with low vaccine-seeking behavior in the population. By delving into these complex factors, this research aims to provide evidence to guide vaccination strategies and interventions in the DRC. Understanding the determinants of vaccination behavior can contribute to the development of more effective approaches to address current and future pandemics across Africa.

2. Methods

This study is reported following the "Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE) statement guidelines [23] and the STROBE checklist is provided in supporting information (**Table S1**).

2.1. Study Settings

This study was conducted in three Health Districts (HDs)—Lukelenge, Muya, and Diulu—located in Mbujimayi, the provincial capital of Kasai-Oriental in central DRC (**Figure 1**).

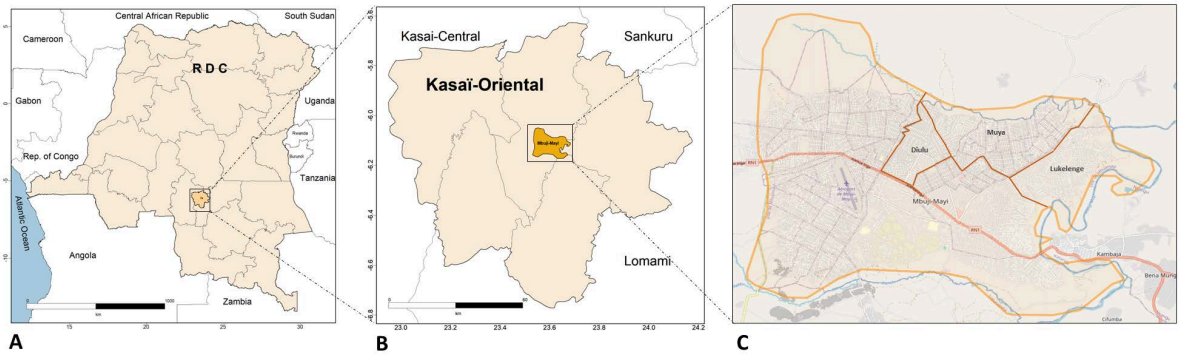

Figure 1. Study areas. This figure delineates the health districts of Diulu, Muya, and Lukelenge, designated as focal study areas, within the Democratic Republic of the Congo (DRC), the province of Kasaï-Oriental, and in Mbujimayi city as illustrated by Panels (A), (B), and (C) respectively.

HDs are responsible for implementing health strategies defined by the National Ministry of Health (MoH) and overseen by the Provincial Health Department (PHD). Each Health District is designed to meet the health needs of a population ranging from 150,000 to 200,000 residents. COVID-19 vaccination commenced in Kinshasa on April 19, 2021, after the arrival of 1.8 million doses of COVID-19 vaccine ChAdOx1-S (AstraZeneca®/Covishield) [14] [19]. Due to slow initial uptake, around 1.44 million doses were at risk of expiring by June and July. To prevent wastage, these doses were redistributed to other African countries [14] [17]. Subsequently, additional vaccines were procured from various donors and initiatives [14] [19]. As shown in **Figure 2**, mass vaccination campaigns in Kasai-Oriental underwent four phases between December 2021 and November 2023, each lasting 7 to 16 days (total, 45 days). Further data regarding the number of vaccines administered during these campaigns would provide valuable insights, but they were not accessible upon request from authorities at the time of conducting the survey.

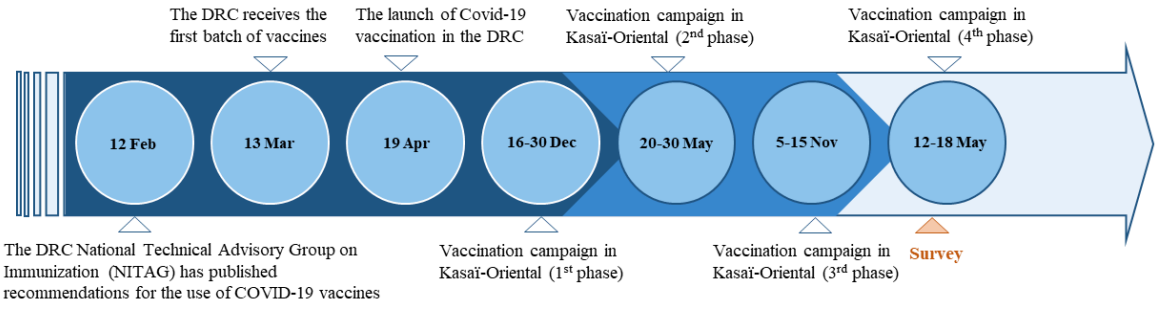

Figure 2. Timeline of vaccination events in Mbujimayi.

This figure situates the survey on the chronology schematizing the main events linked to vaccination against COVID-19 in the population studied. It appears that in total, the population had benefited from 45 days of mass vaccination.

2.2. Study Participants and Design

We conducted a cross-sectional household-based survey in the study area from

May 12th to 18th, 2023, during the fourth phase of COVID-19 vaccination in Mbujimayi. Then, during the survey, a single individual aged 18 and above was recruited within each targeted household on a "first come, first serve" basis. Written informed consent was obtained from each participant before their inclusion, ensuring adherence to ethical standards. Individuals unable to participate due to medical or availability reasons were excluded from the survey to maintain data integrity. Sample size calculations for each HD considered population size and estimated vaccination coverage. With a 50% assumed vaccination coverage [24], a 5% margin of error, 95% confidence interval, and 90% response rate, aiming for a minimum of 422 participants per HD. A minimum of 1266 participants were thus targeted by the field survey.

2.3. Data Collection Process and Study Variables

Ten investigators proficient in Ciluba, the local language, underwent training to administer the survey. The survey units were selected using a multi-stage random sampling technique. A total of three zones, each comprising an equivalent number of wards (19 health wards), were randomly selected from the ten health zones that constitute the town of Mbujimayi. Within each zone, six health areas were randomly selected to form the sample. These neighbourhoods were delineated and subdivided into parcel blocks using satellite images obtained via Google Maps (https://maps.google.com/). Three plot blocks were then randomly selected within each neighbourhood. Finally, within each plot, one adult per household was interviewed using a systematic random sampling procedure with a sampling strategy. They conducted in-depth interviews with individual participants using a standardized semi-structured questionnaire (Additional File 2). This questionnaire was adapted from the International Citizen Project on Coronavirus Disease 2019 (ICPcovid, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7932542/; accessed on 10 February 2021). Prior to its implementation, the questionnaire was field-tested via a pre-survey. It was developed using the open-source KoboToolbox platform (https://www.kobotoolbox.org/) as a mobile web application. It gathered information on participants' sociodemographic characteristics (e.g. age, gender, marital status, education level, religion, and occupation), vaccination status, as well as personal attitude toward COVID-19 and its vaccines. Specifically, it included inquiries about participants' understanding of COVID-19, their vaccination history or intentions, satisfaction with their vaccination status, reasons for vaccine refusal, and perceptions of vaccine effectiveness or safety.

2.4. Definition of Concepts

2.4.1. Categories of Opinions on COVID-19 and Its Vaccines

In this study, participants' personal opinions on COVID-19 were categorized as "correct" if they expressed the view that "COVID-19 is a serious illness requiring protection" in response to the question regarding their perception of COVID-19. Any divergent opinion was classified as a misconception surrounding the disease.

Similarly, participants' personal opinions on the COVID-19 vaccination were considered "correct" if they affirmed the effectiveness, usefulness, and safety of the vaccines.

2.4.2. Vaccine Non-Compliance, Hesitancy, Refusal, and Access Limitation

We operationally defined COVID-19 vaccination non-compliance as not receiving any vaccine dose recommended by national health policies. To assess this, we explored the number of vaccine doses each participant received. Additionally, we delineated vaccine hesitancy from refusal and access limitations. Vaccine hesitancy encompassed a range of behaviors from delayed acceptance to reluctance, without reaching outright refusal, despite the availability of vaccination services. Vaccine refusal refers to the active decision to decline vaccination, regardless of vaccination service availability. In contrast, access limitation involves barriers preventing individuals or communities from obtaining vaccines despite their willingness to be vaccinated.

2.5. Data Analysis

Data analysis was conducted using R software version 4.3.0 (The R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria, 2019). Absolute and relative frequencies summarized qualitative variables, while medians with corresponding Interquartile Ranges (IQRs) described quantitative characteristics. Qualitative variables were compared between groups using the Chi-square test or Fisher's exact test, whereas quantitative variables underwent comparison using parametric tests (e.g. ANOVA test or t-test) or nonparametric tests (Kruskal-Wallis's rank sum test or Wilcoxon rank sum test with correction for continuity), after confirming normality and homogeneity of variances with Shapiro-Wilk's and Levene's tests, respectively. Univariate and multivariate hierarchical Logistic Regression Models (GLMs) assessed potential predictive factors' effect on anti-SARS-CoV-2 vaccine non-compliance. The final model was chosen based on the Akaike's "An Information Criterion" (AIC) values through a stepwise algorithm incorporating both "backward" and "forward" methods. A significance level of $p < 0.05$ was considered for interpreting all statistical tests.

3. Results

3.1. Sociodemographic Characteristics and Clinical Status of Participants

Figure 3 and Table 1 provide an overview of the key sociodemographic characteristics and clinical profiles of the individuals enrolled in this study. Of the initially recruited 1500 individuals, 1496 were successfully included, resulting in a response rate of 99.7%. Notably, 38.4% (n = 575), 31.0% (n = 464), and 30.6% (n = 457) of the participants hailed from the Diulu, Muya, and Lukelenge health districts, respectively. The median age across all participants stood at 33 years (interquartile range, IQR: 23.3), with a predominant age group of 20 to 40 years. Most

participants were female (58.8%), irrespective of their health district of residence. Moreover, participants reported being mostly married (62.0%), adhering to Christianity as their religion (83.8%), and attaining a secondary level of education (55.0%). Approximately one-third of participants (32.2%) identified themselves as unemployed. Notably, all participants met the survey's inclusion criteria by self-reporting apparent good health. Additionally, most of them (91.6%, n = 1354) claimed to have not undergone testing for COVID-19, expressing confidence in not being infected since the pandemic's onset (Table S2). However, 70.9% of respondents (n = 1,030) admitted having experienced symptoms consistent with a possible COVID-19, as defined by the World Health Organization (WHO), over a two-week period, primarily including fever (54.8%) and headache (48.1%).

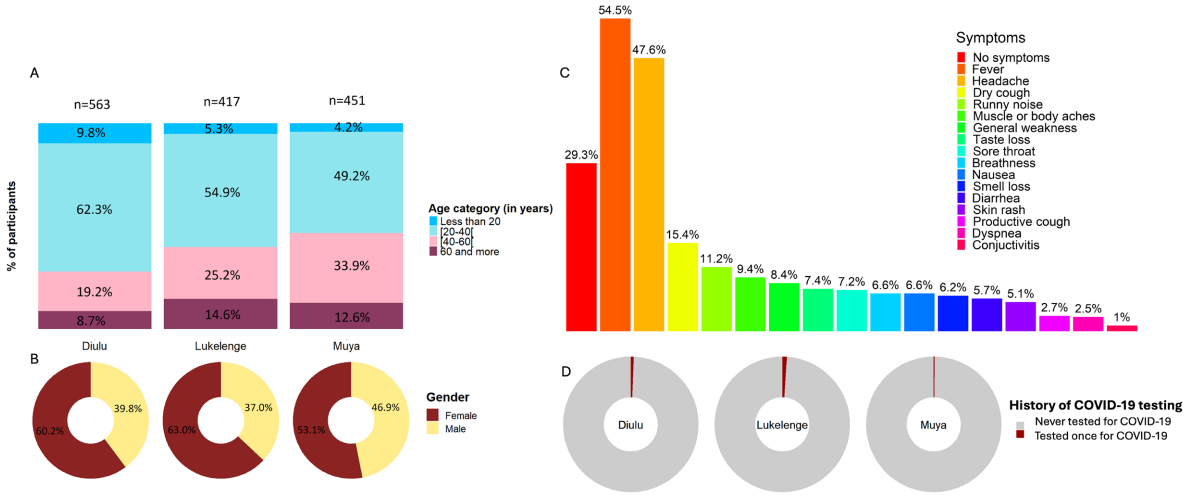

Figure 3. Key sociodemographic characteristics and clinical profiles.

This figure represents the main characteristics of the study participants, including their distribution by age (Panel (A)), gender (Panel (B)), symptoms mentioned (Panel (C)), and COVID-19 testing history (Panel (D)).

Table 1. Sociodemographic characteristics of study participants.

Characteristics	n or median	% or IQR*
Health district		
Diulu	575	38.4
Lukelenge	457	30.6
Muya	464	31.0
Age (in years)	33	23.3
Gender		
Male	617	41.3
Female	879	58.8
Marital status		
Single	414	28.0
Married	916	62.0

Continued

Divorce	27	1.8
Widower	121	8.2
Practiced religions		
Others	91	6.2
Animist	9	0.6
Christian	1339	90.7
Islam	38	2.6
Education level		
Illiteracy	92	6.2
Primary level	284	19.2
Secondary level	814	55.0
College or university level	290	19.6
Type of occupation		
Employment, liberal work or craft work	744	50.4
Unemployed	475	32.2
Schooling	256	17.4

Note: *IQR: Interquartile Range.

3.2. Opinions and Beliefs of Respondents about COVID-19 and Related Vaccines

This study delved into participants' perceptions regarding COVID-19 and its vaccines, as shown in Table 2. Surprisingly, only 35.2% (n = 526) considered COVID-19 as a natural disease posing a significant health threat. Conversely, nearly half held diverse opinions, considering COVID-19 as an artificially created disease to harm people, a disease exclusively affecting certain racial groups, or even as a non-existent or spiritually induced illness. A notable proportion of them (17.8%; n = 266) refrained from expressing an opinion on COVID-19. Regarding vaccines, merely 19.8% (n = 296) believed in their efficacy against COVID-19, while the majority (77.5%) expressed skepticism, deeming them either ineffective, unsafe, or both.

Table 2. Self-reported opinions on COVID-19 and related vaccines.

Opinions	n	%
Which of the following opinions on COVID-19 best reflects your own beliefs?		
"A natural disease which can be a serious health threat"	526	35.2
"A disease created artificially to kill people"	312	20.9
"A disease exclusive to white people"	129	8.6
"A disease that is already ended"	165	11.0
"An imaginary disease that does not exist"	94	6.3
"Belief in a spiritual origin of the COVID-19 illness (e.g. divine punishment of humans or demoniac attack)"	2	0.1
No expressed opinion	266	17.8
Which of the following opinions on COVID-19 vaccines best reflects your own beliefs?		
"They are a good measure to combat COVID-19"	296	19.8

Continued

"They are not effective against COVID-19"	292	19.5
"They are not useful to combat COVID-19"	680	45.5
"They are dangerous for health (e.g. they can kill or make the recipient become infertile)"	187	12.5
No expressed opinions	41	2.7

3.3. Self-Assessed Compliance with Non-Pharmacological Measures to Prevent COVID-19 among Study Participants

Participants were asked to evaluate their compliance with government-imposed non-pharmacological interventions during the pandemic (Table S3). Only 12.7% reportedly adhered to social distancing guidelines of maintaining a 1.5-meter distance in public, and merely 5.7% declared consistently wearing face masks when leaving their home. Additionally, just 24.8% reported regularly coughing or sneezing into their elbows as recommended. Hand hygiene practices were reportedly also suboptimal, with only 19.9% of respondents declaring often washing hands (*i.e.* several times on any occasion) and 28.6% frequently using hand sanitizer (*i.e.* several times on any occasion).

3.4. COVID-19 Vaccine Coverage and Compliance toward Vaccination among the Study Population

Nearly half of participants remained unvaccinated against COVID-19, resulting in an estimated vaccination coverage of 49.1% [95% CI: 47.5; 52.6]. Among the vaccinated individuals (n = 727), 71.8% (n = 522) had received only one vaccine dose, while merely 8.0% (n = 58) had received three or more doses, as shown in Table 3. Primary reasons for vaccination hesitancy or refusal were fear of vaccines and their side effects (38.2%; n = 217) as well as general distrust of vaccines (21.7%; n = 123). The vast majority of those hesitating or refusing the booster dose could not articulate a specific reason for their stance (79.5%).

Table 3. Vaccine uptake and behavior toward vaccination among the study population.

Parameters (n = no. of respondents)	n	%
How many doses of vaccines have you received? (n = 1483)		
"0 dose"	756	50.9
"1 dose"	522	35.2
"2 doses"	147	9.9
"≥3 doses"	58	3.9
Which category best describes you as an unvaccinated person? (n = 756)		
"Eager and planning to get vaccinated, but facing limited access"	247	32.7
"Hesitant to get vaccinated"	230	30.4
"Refusing to get vaccinated"	279	36.9
Which category best describes you as a vaccinated person? (n = 727)		
"Eager and planning to get a booster dose, but facing limited access"	318	43.7
"Hesitant to get a booster dose of vaccine"	169	23.2
"Refusing to get a booster dose of vaccine"	240	33.0

Continued

What is the main reason for not getting the initial vaccine dose? (among unvaccinated, n = 568)		
"I was afraid of the vaccine and its side effects"	217	38.2
"I distrust vaccines in general (all vaccines)"	123	21.7
"I do not know"	149	26.2
"I was feeling sick and could not take the vaccine"	5	0.9
"I trust the vaccine is hazardous to health or life-threatening"	2	0.4
"My religious beliefs prohibit vaccination"	2	0.4
"No trust in COVID-19 vaccine preventive efficacy"	36	6.3
"The COVID-19 vaccine was prohibited because of my pregnancy condition"	22	3.9
"The COVID-19 vaccine was required only for travelers"	1	0.2
"There is no COVID-19 around or the virus does not exist"	1	0.2
"I was very busy and did not have time to go and get a vaccine"	6	1.1
"I deemed I was too young or too old to get the vaccine"	4	0.7
What are reasons for not getting booster dose? (among one or two doses vaccinated, n = 669)		
"I was afraid of the vaccine and its side effects"	14	6.0
"I distrust vaccines in general (all vaccines)"	13	5.5
"I do not know"	187	79.5
No trust in COVID-19 vaccine preventive efficacy	21	8.9

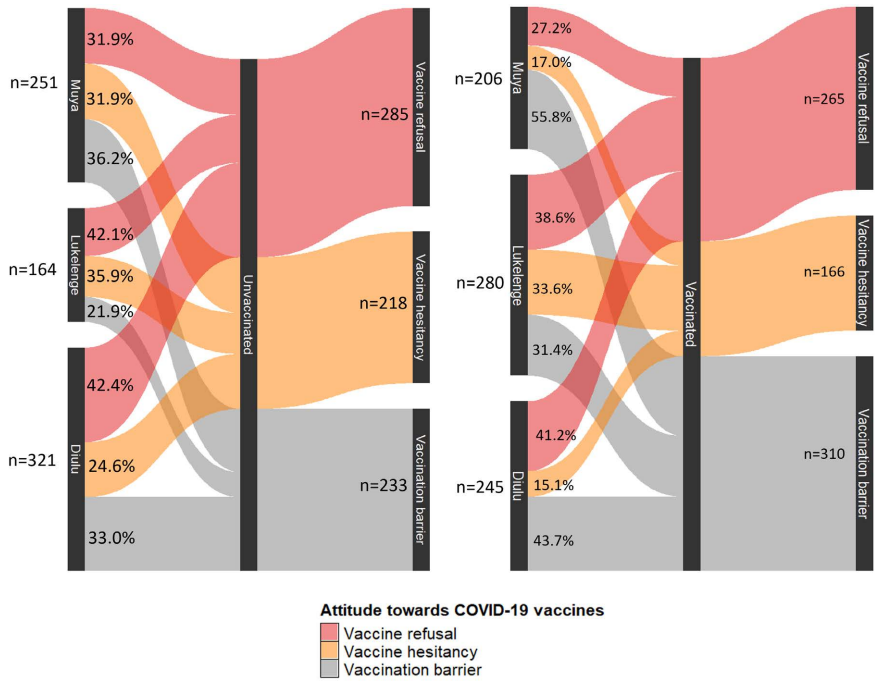

Figure 4. Behavior and attitude towards COVID-19 vaccines or booster doses.

The distribution of vaccine refusal, hesitancy, and access barriers among the study participants is depicted in Figure 4. Out of 756 unvaccinated individuals, a significant majority (67.3%) expressed no clear intention of future vaccination, displaying hesitancy (30.4%) or outright refusal (36.9%). Conversely, 32.7% of this cohort expressed willingness to be vaccinated but reported not having access to vaccines. Moreover, among those who had received one or two doses, only 43.7%

(n = 318) expressed intent to receive a booster dose, while 23.2% (n = 169) were hesitant, and 33.0% (n = 240) outright refused it.

These Sankey diagrams visualize networks of individuals displaying refusal, hesitancy, and access barriers to COVID-19 vaccines (Panel (A)) or vaccine booster doses (Panel (B)) within health districts.

In Tables S4-S6, we assessed the characteristics of participants exhibiting varying attitudes towards COVID-19 vaccination. Participants who outright refused vaccination and booster doses were notably clustered in the Lukelenga health district (OR = 1.5; p = 0.003), in the Diulu health district (OR = 1.7; p < 0.001) among males (OR = 1.3; p = 0.033) and people who were still single (OR = 1.4; p = 0.011). They often harbored misconceptions regarding the nature of COVID-19 (OR = 2.2; p < 0.001) while expressing confidence in their "innate" protection against the virus (OR = 1.5; p < 0.001) and holding skepticism towards the usefulness of vaccines (OR = 0.5; p < 0.001). Conversely, individuals displaying hesitancy towards vaccination and boosters were more frequently identified as residents of the Lukelenge health district (OR = 2.0; p < 0.001). They reported no conviction in their "innate" protection against COVID-19 illness (OR = 4; p < 0.001). While expressing trust in the safety of vaccines (OR = 2.7; p < 0.001), as those who refused vaccines, they were also skeptic of the usefulness of vaccines (OR = 2; p < 0.001). Additionally, this group was more likely to be unemployed (OR = 1.5; p = 0.000). Finally, participants facing limited access to vaccination predominantly hailed from the Muya health district (OR = 2.7; p < 0.001). They exhibited no confidence in their natural protection against COVID-19 (OR = 1.6; p = 0.016).

3.5. Determinants of Vaccination Non-Compliance

We employed hierarchical logistic regression models to explore the determinants of COVID-19 vaccine non-observance, with geographic location treated as a random effect. Our final multivariate model yielded a marginal R^2 of 0.43, indicative of substantial explanatory capability. Key predictors independently associated with vaccine non-adherence encompassed the health district of residency, age, marital status, occupation, and attitudes towards COVID-19 and its vaccines, as illustrated in Figure 5 and Figure S1.

People residing in Diulu and Muya health districts exhibited significantly increased odds of vaccine non-observance compared to those in the Lukalenge health district, with aORs of 3.94 [95% CI: 2.60 - 6.06; p < 0.001] and 3.46 [95% CI: 2.25 - 5.38; p < 0.001], respectively. Single participants exhibited 1.7 times higher odds of non-vaccination compared to married individuals [aOR = 1.66; 95% CI: 1.23 - 2.23; p = 0.002]. Unemployment of participants was linked to 1.6 times higher odds of non-vaccination relative to employment or schooling [aOR = 1.61; 95% CI: 1.18 - 2.21; p = 0.003]. Likewise, participants holding misconception around COVID-19 and its vaccines respectively experienced a 2.1-fold increase [aOR = 2.09; 95% CI: 1.64 - 2.66; p < 0.001] and a 3.3-fold increase [aOR = 3.27; 95% CI: 2.4 - 4.5; p < 0.001] in the likelihood of non-vaccination, compared to those with

accurate perceptions. Conversely, each incremental year in age was associated with approximately a 2% decrease in the odds of vaccine non-observance [aOR = 0.98; 95% CI: 0.97 - 0.99; p = 0.002].

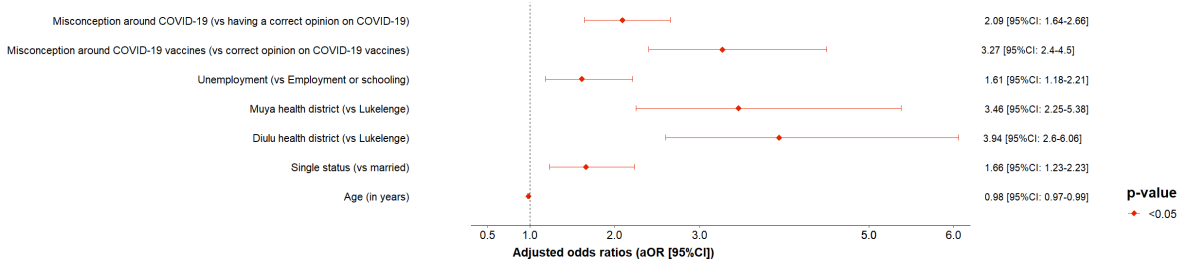

Figure 5. Forest plot of the final hierarchical logistic regression analysis of the likelihood of COVID-19 vaccine non-observance.

The Forest plot presented here elucidates the impact of pivotal factors on the odds of COVID-19 vaccine non-observance within the framework of the final multivariate model. Each horizontal line within the plot depicts the effect of an individual factor, represented as an adjusted Odd Ratio (aOR), delineated by a corresponding box along with its associated 95% confidence interval. Factors positioned to intersect the vertical line set at aOR = 1 indicate negligible influence on non-compliance with COVID-19 vaccination. Conversely, factors positioned away from this line, either above or below, significantly decrease or increase the likelihood of non-compliance, respectively.

4. Discussion

4.1. Vaccine Refusal, Hesitancy, and Access Limitation Significantly Contributed to Low Coverage of COVID-19 Vaccination

The study reveals alarming trends in COVID-19 vaccination uptake, indicating a coverage rate of only 49.1% within the studied population, with many individuals receiving only a single dose. Two years after mass vaccination efforts began, this low uptake deviates from targets set by health ministries and WHO recommendations [8] [14]. This situation could have extended the population's vulnerability to the virus, allowing for ongoing transmission and potentially leading to the emergence of new viral strains [25]. Additionally, it might have imposed extra pressure on the healthcare system and the local economy [14]. The vaccination coverage in the study population likely reflects the broader landscape nationwide, supported by evidence from online surveys and reports indicating approximately 50% coverage across the country [24] [26]. This finding highlights the need for targeted interventions to overcome vaccination barriers and boost community-wide vaccine acceptance in the study population and nationwide.

Refusal, hesitancy, and access limitations likely played varying but significant roles in the low vaccination rates observed in the study population. It is noteworthy that individuals expressing vaccination refusal or hesitancy, as well as those facing access limitations, exhibited distinct profiles, providing valuable insights

for developing targeted strategies to address low vaccination uptake [27] [28]. Vaccine access limitations could indeed be a consequence of global access inequities worsened by the COVID-19 pandemic [29]. Additionally, locally organized brief vaccination campaigns, spanning a total of 45 days divided into 4 phases, may have contributed to lower uptake rates in the study population. Besides population behaviors, challenges hindering vaccination efforts in many resource-limited regions likely encompass inadequate healthcare infrastructure, funding constraints, limited public awareness, and suboptimal government policies [30] [31]. Consequently, the observed low vaccine coverage may be attributed to both vaccine scarcity and inadequacies in vaccination campaign implementation. These findings underscore the importance of optimizing vaccine distribution strategies and enhancing accessibility to achieve broader coverage. Extending the vaccination campaign duration and its integration have the potential to enhance the overall vaccination coverage.

Conversely, more than half of unvaccinated individuals expressed hesitancy or outright refusal of vaccination. Likewise, among those who had received one or two vaccine doses, the majority were hesitant about receiving a booster dose. This reveals a concerning level of reluctance towards COVID-19 vaccination in the population. Consistently, before the initiation of COVID-19 vaccination in the country, surveys conducted in the capital city indicated that the majority of people were not willing to receive the vaccine [32]. Among African countries, the DRC displayed the lowest willingness for COVID-19 vaccination [33]. Respondents' reasons for vaccine reluctance, including a general distrust of vaccines, suggested that this issue may have longstanding roots predating the COVID-19 pandemic. Indeed, there are well-documented historical instances of vaccine hesitancy in the country, such as the mass boycott of the polio vaccine in the 1990s [34]. Effective education campaigns are needed to improve vaccine acceptance and readiness for future health crises that may require vaccination efforts.

Besides, fear of vaccine Adverse Events (AEs) could have also played role in vaccine hesitancy or refusal. While concerns about AEs have been commonly raised with both initial vaccination and boosters across different populations, approved COVID-19 vaccines have demonstrated safety and effectiveness on a global scale [35]-[40]. Reports of AEs such as stroke and myocarditis may have fueled negative campaigns against mass vaccination during the pandemic [38] [41]-[44]. Nonetheless, the benefits of COVID-19 vaccination appeared to outweigh the risks of AEs, thereby reinforcing their recommendation where available [27] [36] [44]-[46]. Additional reasons provided by respondents for not getting vaccinated highlight the significant role of misinformation. Therefore, the spread of misinformation, especially through social networks, and the politicization of scientific knowledge observed during the pandemic likely posed a threat to vaccine acceptance across the country [47] [48]. Moreover, the widespread perception that Africa was less at risk from COVID-19 may have contributed to reinforcing refusals and hesitation, widening the gap between vaccination efforts and vaccination coverage [49]. These findings highlight the need for accurate, evidence-based

information, which should be readily accessible to the population. Moreover, there is a pressing need for the implementation of robust policies to further disseminate knowledge concerning the AEs, effectiveness, and safety of vaccines [50]-[52].

4.2. Misconceptions Surrounding COVID-19 and Its Vaccines, Some Demographic Profiles and Geographic Location Are Main Drivers of Non-Compliance with Vaccination in the Study Population

Factors contributing to non-compliance with COVID-19 vaccines have been extensively examined, revealing a range of predictors, including sociodemographic factors, professional conditions, individual health, perceptions of vaccines, social phenomena, and information received [53] [54]. These factors vary across surveys, necessitating tailored investigations for specific populations [53]-[56].

During the current survey, significant spatial disparities in vaccine uptake were observed across the study area, indicating the need to consider geographic clustering when modeling non-vaccination factors [57]. Residents in certain HDs showed higher odds of vaccine non-compliance, highlighting the importance of equitable spatial distribution of vaccination services. Globally, geographic factors have been pivotal in determining the distribution and accessibility of COVID-19 vaccines, resulting in varying vaccination rates across regions [58]. Urban areas have generally seen more efficient vaccine rollout due to superior health infrastructure and logistical capabilities, whereas rural and suburban areas face challenges in vaccine accessibility and administration [10]. International collaborations have been initiated and have played a crucial role in addressing disparities in vaccine coverage within Africa [59]. However, local-scale spatial variations, such as those observed in this survey, have received less attention in vaccination policies. The Ministry of Health (MoH) established 19 vaccination sites simultaneously, each with similar campaign strategies to serve estimated populations of 479,459, 448,745, or 351,838 inhabitants in Diulu, Muya, or Lukelenge [60].

Age is inversely correlated with vaccine non-observance, with older individuals displaying higher vaccination rates. The influence of age on COVID-19 vaccination has varied across Africa, with some studies reporting higher acceptance among younger age groups [61]-[65]. The DRC's vaccination policies may have influenced the age distribution of vaccinated individuals, initially prioritizing older populations, individuals with comorbidities, and healthcare workers [14] [66]. Over time, eligibility expanded to younger age groups [14]. However, children under 12 and pregnant women remained ineligible, with limited access for those aged 12 to 18. Despite lacking evidence on age groups' roles in disease dynamics, policymakers should have adjusted target populations based on global vaccine safety and efficacy data [40]. Misinformation on social media and perceived lack of severity of COVID-19 among young people may have contributed to hesitancy or refusal to vaccinate.

Marital status independently influenced vaccine observance, with single indi-

viduals having nearly twice the odds of non-observance compared to married counterparts. Inconsistent findings in the literature emphasize the importance of population-specific strategies to enhance vaccine acceptance [53]-[55]. While marital status may not directly impact COVID-19 vaccine compliance, household dynamics and caregiving responsibilities could shape perceptions of vaccine necessity. Married individuals in our study area often reside in multigenerational households, prioritizing vaccination due to caregiving duties, potentially affecting vaccine uptake. Further research is needed in this regard. Additionally, unemployed individuals had 1.61 odds of non-observance compared to their employed counterparts. Occupations with frequent public interaction may heighten perceived exposure risk, prompting vaccination prioritization. Nevertheless, the relationship between profession and vaccination warrants nuanced examination, notably considering healthcare workers' hesitancy despite high exposure risks [67] [68].

Finally, misconceptions about COVID-19 and its vaccines significantly magnified vaccine non-uptake rates 2 to 3 times in the study population. As reported elsewhere [69]-[71], misinformation, often intertwined with specific religious beliefs, could have fueled distrust in COVID-19 vaccination efforts. Targeted public health campaigns are vital to address and correct these misconceptions, fostering confidence in vaccination programs and enhancing pandemic preparedness [71] [72]. Messages should be tailored to reflect sociodemographic characteristics and cultural norms, ensuring accessibility and relevance to diverse populations [73]. Transparency about vaccine development, approval, and dissemination, along with providing information on health policy-making processes and scientific evidence, can help dispel myths and enhance overall vaccine acceptance [73]-[75]. Vaccination campaigns should prioritize equitable access for high-risk individuals and settings to ensure community-wide protection against COVID-19 [76].

4.3. Limitations

This study had several limitations. First, focusing solely on recipients' perspectives may have overlooked systemic issues like supply chain weaknesses. Second, reliance on self-reports could have introduced biases, and age restrictions might have overestimated coverage. Third, findings might not apply to the entire Congolese population due to specific collection sites, and the cross-sectional design could have limited capturing evolving dynamics. Further research in diverse regions is warranted for broader insights. However, given the deceleration of vaccination campaigns, significant changes in coverage post-survey are unlikely.

5. Conclusion

Despite its limitations, this study sheds light on low COVID-19 vaccination rates in the region, likely representative of broader trends in the DRC and tropical Africa. It reveals concerns about vaccine hesitancy and non-compliance, suggesting implications beyond COVID-19. Targeted public health campaigns are crucial to

promote adherence. Misconceptions about COVID-19 and vaccines pose significant challenges, necessitating tailored interventions. Sociodemographic factors and geography affect vaccination rates, highlighting the need for personalized approaches. Building trust, ensuring access, and extending immunization services are vital for optimal coverage and preparing for future outbreaks in the DRC with global perspectives.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Supplementary

Table S1. STROBE statement—checklist of items that are included in the article.

	Item No.	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2 - 3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3 - 4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5 - 6
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13	(*a*) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyses	7
		(*b*) Give reasons for non-participation at each stage	7
		(*c*) Consider use of a flow diagram	12
Descriptive data	14	(*a*) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders	7 - 8
		(*b*) Indicate number of participants with missing data for each variable of interest	5
Outcome data	15	Report numbers of outcome events or summary measures	7 - 8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g. 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12 - 14
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses	26 - 31

Continued

Discussion			
Key results	18	Summarise key results with reference to study objectives	13 - 16
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13 - 16
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

Table S2. Self-reported medical history.

Parameters	n	%
What is your own story with COVID-19 and vaccines?		
"I have been tested and was negative for the virus"	1	0.1
"I have been tested positive for the virus"	9	0.6
"I have not been tested and I don't know if I have contracted the virus"	98	6.6
"I have not been tested and do not think I have contracted the virus"	1354	91.6
"I have not been tested but It's possible that I contracted the virus"	16	1.1
Which of these symptoms have you experienced in the past 2 weeks?*		
Fever	779	54.8
Headache	684	48.1
Sore throat	105	7.4
Taste loss	104	7.3
Smell loss	87	6.1
Stuffy or runny nose	156	11.0
Dry cough	219	15.4
Productive cough	38	2.7
Breathlessness	89	6.3
Muscle or body aches	129	9.1
General weakness	119	8.4
Nausea	96	6.8
Diarrhea	80	5.6
Dyspnea	37	2.6
Conjunctivitis	15	1.1
Skin rush	73	5.1
No symptoms	423	29.1

Note: *Multiple choices possible.

Table S3. Self-assessed compliance with non-pharmacological measures to prevent COVID-19 among study participants.

Compliance with non-pharmacological measures to prevent COVID-19	n	%
On a daily basis, do you feel that you respected the rule of physical distancing when you were in public (e.g. the Congolese government recommended keeping at least 1.5 m between you and others)?		
Yes	187	12.7
No	1288	87.3
How often do you think you were wearing a face mask in public?		
Always (*i.e.* "whenever I'm in public")	27	5.7

Continued

Usually (*i.e.* "five to six times in seven occasions I am in public")	74	15.6
Often (*i.e.* "three to four times in seven occasions I am in public")	112	23.6
Sometimes (*i.e.* "twice in seven occasions I am in public")	147	31.0
Occasionally (*i.e.* "once in seven occasions I am in public")	104	21.9
Never (*i.e.* "not at any occasion I am in public")	10	2.1
On a daily basis, when you cough or sneeze, do you think about doing it into your elbow as recommended by the government?		
Yes	361	24.8
No	1092	75.2
How often do you think you wash hands on a daily basis?		
Often (*i.e.* several times on any occasion)	290	19.9
Sometimes (*i.e.* when hands get dirty, before eating a meal and after using the toilet)	679	46.6
Occasionally (*i.e.* before eating a meal and after using the toilet)	127	8.7
Rarely (e.g. only before eating a meal)	361	24.8
On a daily basis, how often do you think you use a hand sanitizer?		
Frequently (*i.e.* several times on any occasion)	112	28.6
Sometimes (*i.e.* when in contact with other people)	188	48.1
Rarely (*i.e.* only when offered)	91	23.3

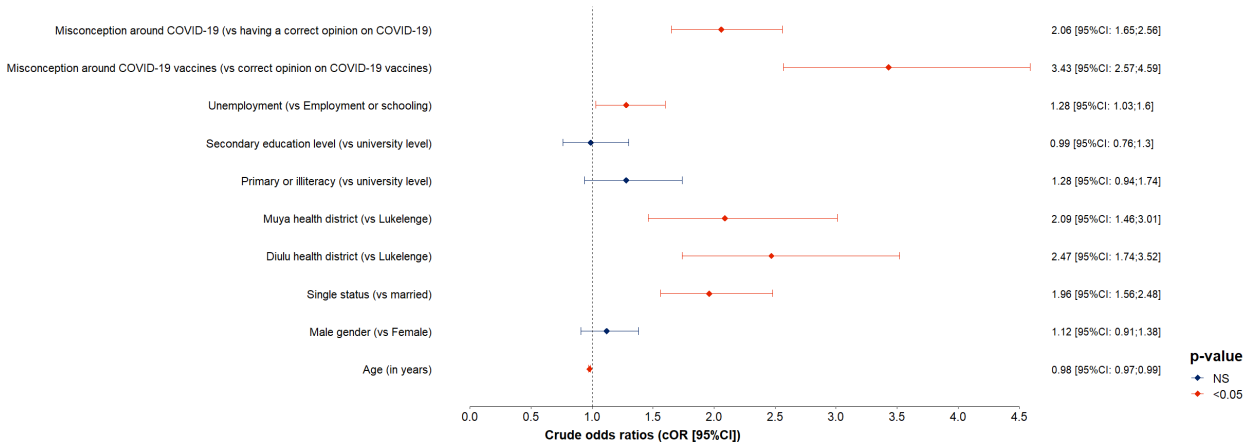

Figure S1. Forest plot of the initial hierarchical logistic regression analysis of the odds of COVID-19 vaccine non-observance.

The Forest plot presented here elucidates the impact of factors on the odds of COVID-19 vaccine non-observance during univariate models. Each horizontal line within the plot depicts the effect of an individual factor, represented as a crude Odds Ratio (cOR), delineated by a corresponding box along with its associated 95% confidence interval. Factors positioned to intersect the vertical line set at cOR = 1 indicate negligible influence on non-compliance with COVID-19 vaccination. Conversely, factors positioned away from this line, either above or below, significantly decrease or increase the likelihood of non-compliance, respectively.

Table S4. Characterization of the participant refusing vaccination or booster doses.

Parameters	Vaccines refusal				OR [95% CI]	p-value
	Yes		No			
	n or M	% or IQR	n or M	% or IQR		
Health district						

Continued

Lukelenge	177	32.2	277	29.9	1.5 [1.1 - 2.0]	0.003
Diulu	237	43.1	329	35.5	1.7 [1.3 - 2.2]	<0.001
Muya	136	24.7	321	34.6	1	
Age in years	32	24.5	33	22.1		0.971
Gender						
Female	304	55.3	569	60.9	1	-
Male	246	44.7	365	39.1	1.3 [1.0 - 1.6]	0.033
Marita status						
Married/widower/divorce	371	68.1	691	74.2	1	-
Single	174	31.9	240	25.8	1.4[1.1 - 1.7]	0.011
Practiced religion						
Christian	459	82.7	779	82.8	1	-
Others	96	17.3	162	17.2	1.0 [0.8 - 1.3]	0.968
Education level						
High (university)	121	22.0	169	18.2	1	-
Intermediate (secondary level)	288	52.4	526	56.6	0.8 [0.6 - 1.0])	0.03
Low (primary or illiteracy)	141	25.6	235	25.3	0.8 [0.6 - 1.1]	0.13
Type of occupation						
Employment or liberal profession	269	49.1	456	49.2	1	-
Unemployment or housework	176	32.1	313	33.8	0.9 [0.8 - 1.2]	0.69
Schooling	103	18.8	158	17.0	1.1 [0.8 - 1.5]	0.50
Self-opinion on COVID-19						
Correct opinion	136	24.5	390	41.4	1	
Misconception	419	75.5	551	58.6	2.2 [1.7 - 2.8]	<0.001
Confidence in one's innate protection against COVID-19						
Yes	423	76.8	644	68.4	1.5 [1.2 - 1.9]	0.001
No	128	23.2	297	31.6	1	
Believe in the safety of vaccines						
Yes	361	65.2	637	67.9	1	
No	193	34.8	301	32.1	1.1 [0.9 - 1.4]	0.276
Believe in usefulness of vaccines						
Yes	128	23.1	365	38.8	0.5 [0.4 - 0.6]	<0.001
No	425	76.9	576	61.2	1	

Table S5. Sociodemographic characteristics of participants hesitant to receive vaccines.

Characteristics	Hesitant to receive vaccines				OR [95% CI]	p-value
	Yes		No			
	n or M	% or IQR	n or M	% or IQR		
Health district						
Lukelenge	153	39.8	301	27.5	2.0 [1.5 - 2.6]	<0.001
Diulu	116	30.2	450	41.2	1	-
Muya	115	29.9	342	31.3	1.3 [0.9 - 1.8]	0.075
Age in years	33	24.2	32,6	23.9		0.186
Gender						
Male	151	39.2	460	41.9	0.9 [0.7 - 1.1]	0.366
Female	234	60.8	639	58.1	1	
Marita status						

Continued

Single	108	28.1	306	28.0	1.0 [0.8 - 1.3]	0.969
Married/widower/divorce	276	71.9	786	72.0	1	
Practiced religion						
Christian	324	83.3	914	82.6	1	
Others	65	16.7	193	17.4	1.0 [0.7 - 1.3]	0.745
Education level						
High (university)	67	17.5	223	20.3	1	
Intermediate (secondary level)	205	53.5	609	55.5	1.1 [0.8 - 1.5]	0.480
Low (primary or illiteracy)	111	29.0	265	24.2	1.3 [0.9 - 2.0]	0.063
Type of occupation						
Unemployment or housework	155	40.6	334	30.6	1.6 [1.2 - 2.0]	<0.001
Employment or liberal profession	167	43.7	558	51.1	1	
Schooling	60	15.7	201	18.4	1.0 [0.7 - 1.4]	0.988
Self-opinion on COVID-19						0.924
Right	136	35.0	390	35.2	-	
Wrong	253	65.0	717	64.8	1.0 [0.8 - 1.3]	
Confidence in one's innate protection against COVID-19						
Yes	190	48.8	877	79.5	1	
No	199	51.2	226	20.5	4.0 [3.2 - 5.2]	<0.001
Believe in the safety of vaccines						
Yes	314	81.3	684	61.8	2.7 [2.0 - 3.6]	<0.001
No	72	18.7	422	38.2	1	
Believe in usefulness of vaccines						
Yes	88	22.6	405	36.7	0.5 [0.4 - 0.7]	<0.001
No	301	77.4	700	63.3	1	

Table S6. Sociodemographic characteristics of participants with difficulty in access to vaccines.

Characteristics	Difficulty in access to vaccines				OR [95% CI]	p-value
	Yes		No			
	n or M	% or IQR	n or M	% or IQR		
Health district						
Lukelenge	31	22.3	261	27.3	1.2 [0.8 - 2.0]	0.375
Diulu	41	29.5	431	45.0	1	
Muya	67	48.2	265	27.7	2.7 [1.8 - 4.1]	<0.001
Age in years	30.1	18.5	32	22.9		0.116
Gender						
Male	55	39.9	410	42.8	0.9 [0.6 - 1.3]	0.507
Female	83	60.1	547	57.2	1	
Marita status						
Single	42	30.4	289	30.3	1.0 [0.6 - 1.5]	**0.979**
Married/widower/divorce	96	69.6	664	69.7	1	
Practiced religion						
Christian	124	89.2	800	82.8	1	

Continued

Others	15	10.8	166	17.2	1.7 [0.9 - 3.1]	**0.057**
Education level						
High (university)	22	15.9	189	19.8	1	
Intermediate (secondary level)	84	60.9	503	52.7	1.4 [0.9 - 2.4]	0.154
Low (primary or illiteracy)	32	23.2	262	27.5	1.0 [0.6 - 1.9]	0.870
Type of occupation						
Unemployment or housework	51	37.2	322	33.8	1.1 [0.7 - 1.7]	**0.534**
Employment or liberal profession	63	46.0	451	47.3	1	-
Schooling	23	16.8	181	19.0	0.9 [0.5 - 1.5]	0.715
Self-opinion on COVID-19						
Right	48	34.5	290	30.0	1	
Wrong	91	65.5	676	70.0	0.8 [0.6 - 1.2]	**0.280**
Believe being protected against COVID-19						
Yes	79	56.8	646	67.2	1	
No	60	43.2	316	32.8	1.6 [1.1 - 2.3]	**0.016**
Believe in the safety of vaccines						
Yes	103	74.1	691	71.8	1.1 [0.8 - 1.7]	**0.565**
No	36	25.9	272	28.2	1	
Believe in usefulness of vaccines						
Yes	41	29.5	228	23.6	1.4 [0.9 - 2.0]	**0.132**
No	98	70.5	737	76.4	1	