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COVID-19 vaccination refusal trends in Kenya over 2021

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ABSTRACT

Background: Vaccination refusal exacerbates global COVID-19 vaccination inequities. No studies in East Africa have examined temporal trends in vaccination refusal, precluding addressing refusal. We assessed vaccine refusal over time in Kenya, and characterized factors associated with changes in vaccination refusal.

Methods: We analyzed data from the Kenya Rapid Response Phone Survey (RRPS), a household cohort survey representative of the Kenyan population including refugees. Vaccination refusal (defined as the respondent stating they would not receive the vaccine if offered to them at no cost) was measured in February and October 2021. Proportions of vaccination refusal were plotted over time. We analyzed factors in vaccination refusal using a weighted multivariable logistic regression including interactions for time.

Findings: Among 11,569 households, vaccination refusal in Kenya decreased from 24 % in February 2021 to 9 % in October 2021. Vaccination refusal was associated with having education beyond the primary level (−4.1[−0.7,−8.9] percentage point difference (ppd)); living with somebody who had symptoms of COVID-19 in the past 14 days (−13.72[−8.9,−18.6]ppd); having symptoms of COVID-19 in the past 14 days (11.0[5.1,16.9]ppd); and distrusting the government in responding to COVID-19 (14.7[7.1,22.4] ppd). There were significant interactions with time and: refugee status and geography, living with somebody with symptoms of COVID-19, having symptoms of COVID-19, and believing in misinformation.

Interpretation: The temporal reduction in vaccination refusal in Kenya likely represents substantial strides by the Kenyan vaccination program and possible learnt lessons which require examination. Going forward, there are still several groups which need specific targeting to decrease vaccination refusal and improve vaccination equity, including those with lower levels of education, those with recent COVID-19 symptoms, those who do not practice personal COVID-19 mitigation measures, refugees in urban settings, and those who do not trust the government. Policy and program should focus on decreasing vaccination refusal in these populations, and research focus on understanding barriers and motivators for vaccination.

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1. Introduction

In the second year of the pandemic, 2021 was punctuated by global inequities in COVID-19 vaccination delivery and distribution. As of December 2021, 57.6 % of the world's population had received at least one vaccine dose, yet only 8.4 % of people in low-income countries had been vaccinated for COVID-19 (increasing only to 17.8 % in June 2022) [1]. This inequity has been a major contributing factor to the almost four million deaths attributable to COVID-19 globally in 2021, and the emergence of new strains of COVID-19 [2,3]. The World Health Organization (WHO) developed the "Measuring Behavioural and Social Drivers of Vaccination (BeSD)" framework (Fig. 1) as a tool to measure and address vaccination uptake [4]. The BeSD framework includes consideration of practical issues that contribute to vaccination inequities, including supply of vaccines and associated products (e.g. dilutants and syringes) to low and middle-income countries, with stockpiling, export restrictions, and price gouging contributing to the supply crisis; a lack of infrastructure, including freezers and transportation equipment; and a lack of trained staff, especially nursing staff for whom there is a shortage of 6 million globally [5]. However, at the heart of the BeSD framework is motivation for vaccination, influenced by 'what people think and feel' and social processes [4].

While factors and rates of vaccination refusal have been well studied in high-income countries (HICs), very few studies have examined COVID-19 vaccination refusal in low and middle income countries, particularly in East Africa [6–8]. A recent study using cross-sectional data from February 2021 in four Kenyan counties found that 60 % of respondents were vaccination hesitant and identified factors associated with vaccination refusal including older age, lower education, not adhering to COVID-19 mitigation strategies, and concerns with the safety and effectiveness of the vaccine [6]. However, given the rapidly changing landscape of COVID-19 beliefs, exposures, and vaccination programs, rates of and factors contributing to refusal may have changed in Kenya during 2021. Studies from the United States have found decreases in vaccination refusal over time [9,10]. However, no study to date has examined longitudinal trends in vaccination refusal in low-income countries.

Using data from the World Bank Rapid Response Phone Surveys (RRPS), we examine vaccination refusal between January and October of 2021 in Kenya, a country which had a vaccination rate below 10 % at the end of 2021 [1]. We aim to 1) establish rates of vaccination refusal throughout the year; and 2) examine the social process factors associated with vaccination refusal, and how/if they are affected by time. We hope that this analysis will assist policy makers and public health agencies in Kenya in identifying those who are most at risk of being vaccination hesitant; and will offer insight into how rates of refusal may change in the future in Kenya and similar countries, especially in Sub-Saharan Africa.

2. Methods

2.1. Data source

We used publicly available, de-identified data from the Rapid Response Phone Surveys in Kenya that were administered by the World Bank in collaboration with the University of California, Berkeley, the United Nations High Commissioner for Refugees (UNHCR), and the Kenyan National Bureau of Statistics. Data were collected longitudinally from a cohort of households over six rounds between May 2020 and October 2021, with replacements sought for dropouts. Data were collected at the household level by mobile phone calls, using a list generated from the 2015/16 Kenya Integrated Budget Household Survey, Random Digit Dialing (calling random phone numbers), and UNHCR's proGres database of registered refugees in Kenya. The survey was meant to be representative of the entire population of Kenya (including a representative proportion of refugees), with weights included to adjust for differences in mobile phone ownership. For this study, we only used data collected in 2021 (January–October), and data from the primary respondent, as these data included questions on COVID-19 vaccination acceptance. More information on the data source, including ethics, is available from World Bank and UNHCR Microdata Libraries [11].

2.2. Variables

The primary outcome was COVID-19 vaccination refusal, measured by the question "Would you agree to be vaccinated if the vaccine was available at no cost," with possible responses being yes and no. Predictor variables we included were demographics (refugee status and geography, age, gender, and education), exposure to COVID-19 (living with somebody who had symptoms of COVID-19 in the past 14 days), if the respondent had symptoms of COVID-19 in the past 14 days, if the respondent washes their hands more because of COVID-19, if the respondent trusts the kenyan government's response to COVID-19, and information and misinformation. Information on the full wording of these variables and transformations for misinformation and information can be found in Appendix I.

2.2.1. Analysis

We conducted the data analysis using Stata SE 17 [12]. We plotted the proportion of respondents who reported vaccination refu-

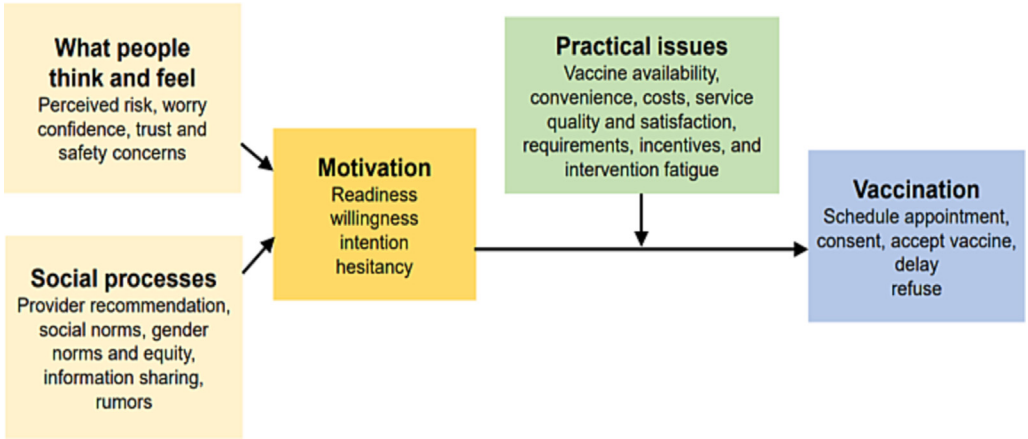

Fig. 1. BeSD Framework for vaccination Equity (WHO).

sal over the course of 2021 using a fractional polynomial plot with 95 % confidence intervals. We also summarized the proportions of each predictor variable in each month [13].

2.2.1.1. Survey design and weighting. To account for clustering over time, we declared a survey design in which the primary sampling unit was the household, and the strata was the pre-defined strata in the dataset. We also used cross-sectional household weights as the weighting term. It is worth noting that we analyzed time as calendar months, and that each household has one observation per wave (a three-month period) rather than by month.

2.2.1.2. Adjusted analysis. For the adjusted analysis, we declared a survey design with the individual household as the sampling unit and population weights applied to represent the entire Kenyan population. Observations with missing data for the predictor and response variables were excluded. An adjusted multivariate regression was run to estimate the impacts of the predictor variables on vaccination refusal, including interactions for these variables and months (as continuous variables), with non-significant interactions removed (above p = 0.05). The model can be found in Appendix II. A random forest model was used to check for additional interactions. Results are presented as plotted marginal effects and marginal probabilities that present the predicted vaccination refusal at each level of all predictor variables in the model averaged over observed values of all the other covariates in the model.

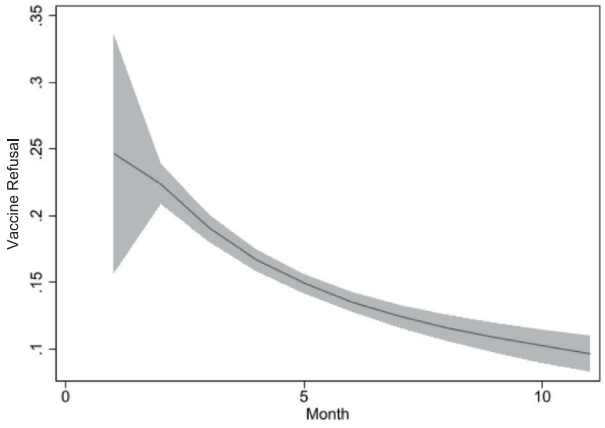

Fig. 2. A fractional polynomial fit graph (with 95 %CI) showing monthly vaccination refusal rates in among the sampled population between January and October 2021.

3. Results

The dataset contained 38,908 households in rounds four to six. As some were questioned in multiple rounds, this comprised of 10,138 distinct households. There were 27,339 households which had missing data for key variables. These were removed, leaving 11,569 households. One of the key variables as described in past studies, if the respondent trusted the government in responding to COVID-19, was asked randomly to half of the respondents. This accounted for 92 % of missingness. The remaining 8 % of missingness was due respondents declining to answer individual questions.

3.1. Descriptive Statistics

Overall, vaccination refusal decreased throughout 2021, from 24 % in February 2021 to 9 % in October 2021 (Fig. 2, Table 1). The demographic trends and other predictors were estimated to be consistent throughout the data collection period, other than a decrease in the proportion of respondents who did not trust the government's COVID-19 response (Table 1).

3.2. Adjusted analysis

Fig. 3 presents the marginal effects of the predictors, estimated from the logistic regression model (the model as well as a table of the marginal effects can be found in Appendix II). From the

Table 1
Summary table presenting frequencies and unweighted rates of key variables, broken down by month during 2021. N(%).

	Total N = 11,569	January N = 46	February N = 1,220	March N = 1,634	April N = 1,956	May N = 2,457	June N = 698	July N = 671	August N = 1,099	September N = 923	October N = 865
Vaccination hesitant	1,785 (15 %)	11 (24 %)	279 (23 %)	298 (18 %)	330 (17 %)	375 (15 %)	100 (14 %)	68 (10 %)	137 (12 %)	106 (11 %)	81 (9 %)
Refugee in Camp	1,866 (16 %)	28 (61 %)	268 (22 %)	177 (11 %)	298 (15 %)	416 (17 %)	116 (17 %)	125 (19 %)	161 (15 %)	141 (15 %)	134 (15 %)
Refugee in Urban	511 (4 %)	1 (2 %)	87 (7 %)	39 (2 %)	89 (5 %)	118 (5 %)	24 (3 %)	29 (4 %)	47 (4 %)	53 (6 %)	22 (3 %)
National in Rural	4,391 (38 %)	7 (15 %)	411 (34 %)	721 (44 %)	737 (38 %)	947 (39 %)	280 (40 %)	214 (32 %)	393 (36 %)	334 (36 %)	346 (40 %)
National in Urban	4,807 (42 %)	10 (22 %)	454 (37 %)	697 (43 %)	832 (43 %)	976 (40 %)	278 (40 %)	303 (45 %)	498 (45 %)	395 (43 %)	363 (42 %)
Age	40 (14)	39 (15)	39 (14)	40 (14)	40 (14)	39 (14)	40 (13)	40 (14)	40 (14)	40 (14)	40 (13)
Sex (Female)	6,137 (53 %)	18 (39 %)	625 (51 %)	872 (53 %)	1,016 (52 %)	1,327 (54 %)	362 (52 %)	349 (52 %)	583 (53 %)	505 (55 %)	479 (55 %)
Education beyond Primary	6,808 (59 %)	18 (39 %)	631 (52 %)	945 (58 %)	1,113 (57 %)	1,469 (60 %)	440 (63 %)	411 (61 %)	699 (64 %)	557 (60 %)	522 (60 %)
HH Member w/ COVID symptoms	731 (6 %)	1 (2 %)	81 (7 %)	116 (7 %)	139 (7 %)	188 (8 %)	36 (5 %)	35 (5 %)	53 (5 %)	40 (4 %)	42 (5 %)
Currently has COVID Symptoms	2,426 (21 %)	11 (24 %)	280 (23 %)	298 (18 %)	399 (20 %)	514 (21 %)	145 (21 %)	147 (22 %)	238 (22 %)	224 (24 %)	170 (20 %)
Disagree Gov Trust	1,050 (9 %)	3 (7 %)	120 (10 %)	184 (11 %)	206 (11 %)	275 (11 %)	68 (10 %)	55 (8 %)	65 (6 %)	43 (5 %)	31 (4 %)
Neutral Gov Trust	2,710 (23 %)	22 (48 %)	255 (21 %)	366 (22 %)	539 (28 %)	583 (24 %)	151 (22 %)	137 (20 %)	188 (17 %)	238 (26 %)	229 (26 %)
Agree Gov Trust	7,815 (68 %)	21 (46 %)	845 (69 %)	1,084 (66 %)	1,211 (62 %)	1,599 (65 %)	479 (69 %)	479 (71 %)	846 (77 %)	642 (70 %)	605 (70 %)
Last week, did you – Wash hands more than used to	10,880 (94 %)	38 (83 %)	1,153 (95 %)	1,503 (92 %)	1,844 (94 %)	2,297 (93 %)	643 (92 %)	636 (95 %)	1,051 (96 %)	887 (96 %)	823 (95 %)
Information Score	11 (1)	9 (2)	10 (1)	11 (1)	11 (1)	11 (1)	11 (1)	11 (1)	11 (1)	11 (1)	11 (1)
Misinformation Score	1 (1)	2 (3)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)

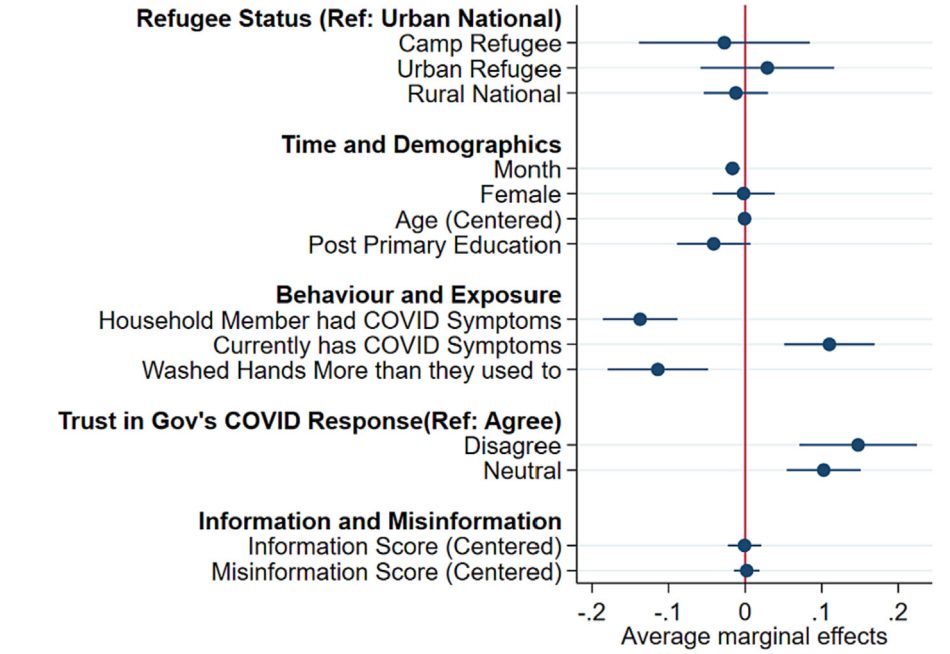

Fig. 3. Marginal Effects of Key Variables on vaccination refusal adjusted for interactions.

adjusted model, we estimated that vaccination refusal decreased by 1.6[95 %CI: 0.7,2.6] percentage point difference (ppd) per month. The decline was quite broad-based and there was no significant marginal difference between being a Kenyan national living in an urban setting and being a Kenyan national in a rural setting, or a refugee in an urban or camp based setting. We also saw no significant marginal differences by age or sex; though having an education beyond the primary level was associated with a 4.1[0.7,8.9] reduction in vaccination refusal.

Those who resided with somebody who had symptoms of COVID-19 in the past 14 days were 13.72[8.9,18.6] ppd less likely than their counterparts who did not live with such a person to be vaccination hesitant. Conversely, those respondents who themselves had symptoms of COVID-19 in the past 14 days were 11.0 [5.1,16.9] ppd more likely to be vaccine hesitant.

When examining behavior and beliefs, those who reported washing their hands more often than they did before the COVID-19 pandemic were 11.4[4.8,17.0] ppd less likely to be vaccination hesitant. Those who disagreed or were neutral with the statement, "I trust the Kenyan government in responding to the COVID-19 pandemic" were more likely to be vaccination hesitant than those who agreed (14.7[7.1,22.4] ppd and 10.3[5.4,15.1] ppd, respectively). No significant marginal effects were estimated for the misinformation and information scores.

We examined whether the rate of decline in vaccine refusal varied across the levels of our primary predictors by estimating an interaction between time and some of the variables, as is illustrated in Fig. 4. For refugee status and setting, we found that camp based refugees saw a substantial drop in marginal probability of being vaccination hesitant over time, while there was a more modest drop for urban refugees and both urban and rural Kenyan nationals. There was also a larger drop over time for those who reported residing with somebody who had symptoms of COVID-19 in the past 14 days compared to those who did not; the opposite was seen for those who reported themselves having symptoms of COVID-19 in the past 14 days. Despite not having an effect when averaged across the population without interactions, there was also a larger drop in the marginal probability of being vaccination hesitant over time for those who believed in higher levels of misinformation (represented by the misinformation score) than those who believed in less.

4. Discussion

In this study, we aimed to examine trends and factors in vaccine refusal over 2021 in Kenya. To the authors' knowledge, this is the first published study to examine temporal trends in COVID-19 vaccination outside of a high income country. We estimated that rates of COVID-19 vaccination refusal decreased dramatically through 2021, from 24 % in January 2021 to 9 % in October 2021. With vaccination motivation at the heart of the WHO's BeSD framework for vaccination equity, this suggests substantial strides in achieving vaccination equity in Kenya [4]. We also found that several factors, from both the 'what people think and feel' and 'social processes' inputs of the BeSD model are associated with vaccination refusal, both independently and when interacted with time.

4.1. Temporal trends in vaccination refusal over 2021

Our estimates that refusal to COVID-19 vaccination decline over time are in line with those from the US. Liu and Li (2021) estimated that vaccination refusal in the US dropped from 21.8 % to 15.9 % between January and March 2021, primarily driven by a reduction in refusal in the Black population [10]. King et al. (2021) estimated that vaccination refusal dropped from 25.4 % to 16.5 % between January and May 2021, largely due to decreases in refusal among Black, Hispanic, and Pacific Islander groups; and those who did not progress beyond secondary education [9]. Lavoie et al. (2021), however, found in Canada that vaccination refusal did not change significantly between May 2020 and March of 2021. It is worth noting however that the earlier rounds of this latter study were based on a hypothetical vaccine, and that even in the later rounds of early 2021 the vaccine was still not available in Canada [14].

Using Kumar et al. (2022) temporal model for degrees vaccination refusal (which is driven by societal reactions to vaccinations), we may partially be able to explain our results [15]. The model

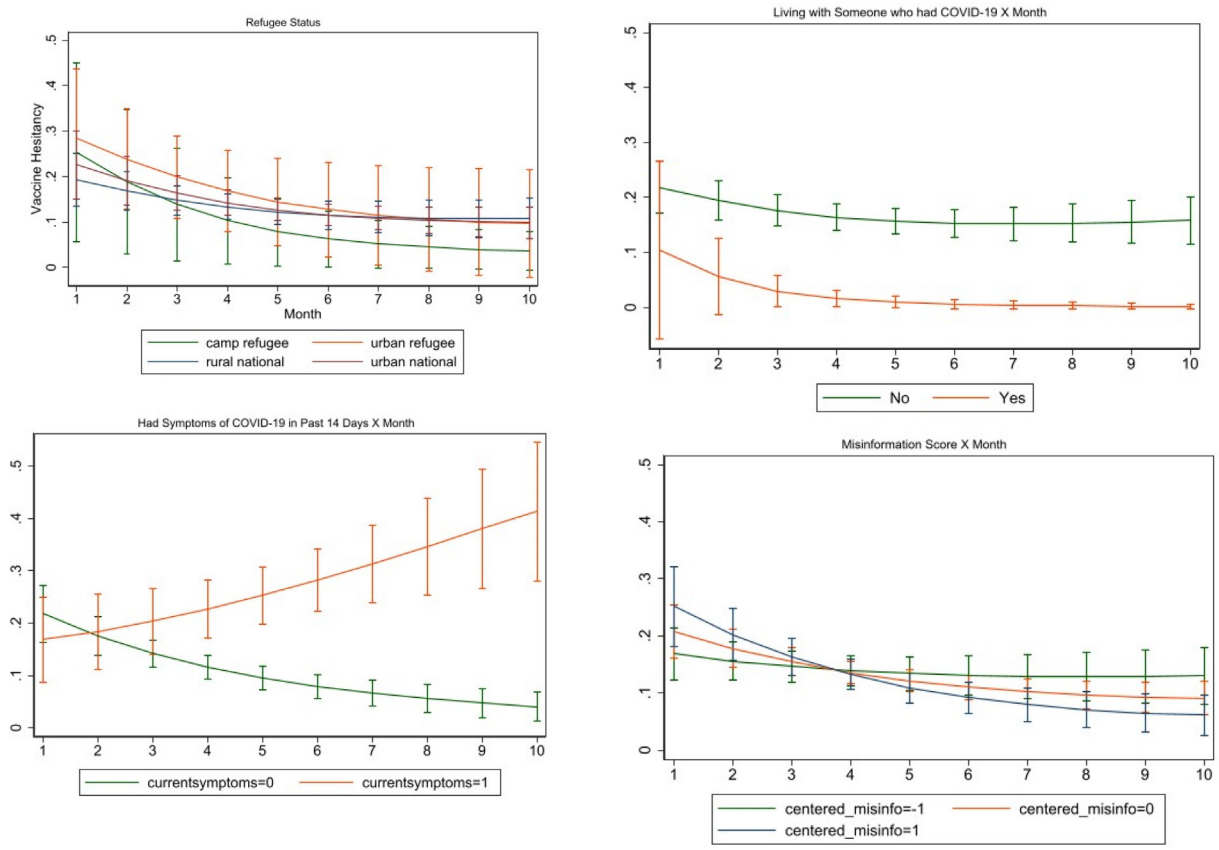

Fig. 4. Marginal Probability Plots of vaccination refusal for Interaction Terms (with 95 %Cis).

describes phases of degrees of vaccination refusal as: 1) vaccination eagerness, 2) vaccination ignorance, 3) vaccination resistance, 4) vaccination confidence, 5) vaccination complacency and 6) vaccination apathy. While the trends seen in our results do not fully comport with this model (e.g., one would expect to see an initial low level of vaccination refusal, which increases up to phase three, and steadily decreases and levels out), our results are consistent with phase three (vaccination resistance) in early 2021, followed by a rapid transition to phase five, and the leveling out on the proportion of vaccination hesitant individuals later in 2021 as phase six. The transition from vaccination resistance to vaccination confidence was likely driven by those who were originally only marginally vaccination hesitant, rather than rigidly resistant, as King et al. (2021) saw in their US study [9]. These groups likely adopted a 'wait and see' attitude to the vaccination program. Indeed, from a study in South Africa, 23 % of those who were vaccination hesitant in early 2021 stated the vaccine progressing through trials too quickly as their reason for hesitance [16]. Additionally, those who were afraid of side effects may have seen their peers being vaccinated with minimal side effects, promoting uptake. Thirty percent of those in the South Africa study cited fear of side effects as a reason for hesitance [16].

Contributing to a transition from resistance to confidence, people may not have seen themselves at risk of COVID-19 infection, mild to severe morbidity, or mortality. This was cited as a reason for vaccination refusal among 10 % of the respondents in South Africa [16]. It is likely that over the course of 2021 people saw members of their family or community afflicted with COVID-19 which led to fear of contracting the virus alone, or fear of contracting the virus and having severe morbidities or mortality. This is especially profound considering that the later period of our analysis included the delta wave, which was caused a profound burden of morbidity in Kenya [17]. Indeed, in our study, we saw those interactions between temporality and knowing somebody with COVID decreased vaccination refusal. It is worth noting, however, that the interaction between temporality and having symptoms of COVID increased refusal, possibly due to the belief that they are now immune, that they need to be fully recovered before receiving the vaccine, or that COVID does not affect them badly.

4.2. Social processes in vaccination refusal and key considerations for public health programming

The first of two inputs into motivation on the BeSD model is social processes in vaccination refusal, such as recommendations by health providers, social norms including gender and age norms, equity, and information and misinformation. We explored these through examinations of demographics and beliefs in information and misinformation.

4.2.1. Demographics

The first demographic which we examined was refugee status and geographic setting. While, when averaging across time and other variables, this did not significantly impact vaccination refusal; a significant interaction was seen between refugee status and geographic setting and time. Status as a refugee residing in a camp drastically decreased the marginal probability of being vaccination hesitant over time, while refugees in urban settings and Kenyan nationals in both urban and camp based settings did not see a significant decrease over time. Reasons for this are unclear, and require further investigation as there may be important learned lessons from the Kenyan refugee camps.

Gender and age did not have a significant impact on vaccination refusal. While this is not to say that identical interventions can be applied to each group, vaccination programming should pay equal attention based on this demographic (unless there are other compelling factors, such as the clinical impact of age). We did find however that those educated beyond the primary level were less likely to be vaccination hesitant. As such, particular attention should be paid to vaccination promotion among those with lower levels of education.

4.2.2. Misinformation and information

When averaging for temporality there was no association seen between vaccination refusal and belief in information and misinformation. However, counterintuitively we estimated a more significant decrease in the marginal probability of being vaccination hesitant over time for those who believed in more misinformation than those who did not. The reasons for this are unclear and require further investigation.

4.3. "What People Think and Feel" in vaccination refusal and key considerations for public health programming

The second of two inputs into motivation in the BeSD model is 'what people think or feel' regarding vaccinations, such as perceived risk in both the vaccination and the disease, confidence, trust, and concerns about side-effects. We explore these through looking at behaviour with regards to COVID, past exposures of COVID, and trust in the government.

4.3.1. Behaviour and exposure

We also found that, independent of temporality, living with somebody who had COVID-19 symptoms in the past 14 days, and increased hand washing as a risk reduction measure, are associated with reduced vaccination refusal. These findings are supported by studies from other, primarily high-income countries: in both Sweden and Hong Kong that those who accept personal preventive measures, such as hand washing, are more likely to be vaccinated - a factor that has been well established [18,19]. No studies however have looked at the impact of having household COVID-19 contacts on vaccination refusal, though we suspect this may be due to an increased awareness of exposure. To this point, it was estimated that by June 2021, 75 % of Kenyans would have had exposure to COVID-19, with that number only increasing over time [20]. As a policy implication, COVID-19 vaccination programs should target those who are identified as contacts of people living with COVID-19.

Conversely, we found that if the respondent personally had symptoms of COVID-19 in the past 14 days they were more likely to be vaccination hesitant, particularly those surveyed towards the end of 2021. This is likely due to misbelief that COVID-19 infection causes a suitable immune response. As a policy implication, education programming should target those who have COVID-19, and spread information combatting the misbelief that COVID-19 infection is a suitable substitute for the vaccine. Alternatively, this may also be due to concern over being vaccinated while still infectious: another point for education.

4.3.2. Government trust

We found that those who did not trust the Kenyan government in responding to COVID-19 were more likely to be vaccination hesitant than those who did. These results are similar to those suggested by Afolabi et al. (2021), and empirically demonstrated by Trent et al. (2021) in Australia [21,22]. Further, in both Austria and South Korea, government trust was found to be correlated with vaccination willingness [23,24]. However, Trent et al. (2021) did report that in some American cities government distrust was associated with a decrease in vaccination refusal: likely due to the survey being administered during a conservative administration which was associated with COVID-19 minimization and vaccination mistrust. This is worth noting when interpreting the results for policy implementation, particularly when there is a shift in the government's political orientation. At a policy level, promotion activities should therefore focus on those who do not trust the government in countries where the government is seen as pro-vaccination, with the opposite in countries where the government is seen as anti-vaccination.

4.4. Strengths and limitations

While there are several limitations to consider, we attempt to mitigate these. First, the primary question asked was hypothetical - if the vaccination was actively offered to the respondent, they may have responded differently. However, this was likely reduced through assurances of confidentiality. Secondly, participant responses may have been subject to social desirability bias. This may especially be the case at later stages of the survey, when social desirability bias may be stronger given repeated questioning [25,26]. This was likely minimized given the promises of confidentiality as well as phone interviewing [27]. Thirdly, only the primary respondent, most often the household head, was questioned, rather than other members which may present bias. Finally, the survey only included those with access to mobile phones, though sampling weights were designed to counteract this. There are several important research questions not addressed by this study, which warrant future investigation (e.g. how do lockdowns, school closures, and other public health actions impact refusal). Despite these limitations, the survey utilized a large sample representative of the Kenyan population.

5. Conclusion

This study found that COVID vaccination refusal has decreased dramatically over the course of 2021 in Kenya, from 24 % in February 2021 to 9 % in October 2021. This suggests some degree of success on the part of the Kenyan Government, as well as confirmation that several temporal factors address vaccination refusal over time. However, despite the significant drop in vaccination refusal in Kenya, the country's full vaccination rate remained below 10 % at the end of 2021. As such it is likely access to vaccinations, not motivation, that is the core issue in achieving vaccination equity in Kenya (and likely in many other low income countries). Indeed, the COVID-19 vaccine was only available at a limited basis to key populations such as health care providers and the elderly from March 2021, with the general population not being eligible for vaccination late 2021. Alongside this, it's also worth considering that vaccinations were predominantly available in health centers, rather than through outreach services, which may have precluded access. As such, attention should be paid to delivering vaccines where they are needed: increasing the supply of vaccines across the country and related products, building transport and physical infrastructure, and providing trained staff to administer immunizations. However, to achieve vaccination equity in Kenya it is also important to convince Kenyans who remain vaccination refusers. Targeting those with lower education, who do not trust the government, who recently had symptoms of COVID-19, and/or do not practice personal COVID mitigation measures with vaccination promotion programming through both interventions and further research to support such interventions.

6. Disclaimers

The views expressed in this paper are those of the authors and do not necessarily reflect those of the World Bank.

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Data availability

Data is publically available and cited

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix I. Scaling of information and misinformation variables

- The variables used to create the information score are as follow:
- The use of masks in public would reduce the risk of contracting COVID-19 (1 being disagree, 2 being neutral, 3 being agree)
- Washing hands or using hand sanitizer reduces the risk of contracting COVID-19 (1 being disagree, 2 being neutral, 3 being agree)
- Keeping at least two meters/ two arms length distance from others reduces the risk of contracting COVID-19 (1 being disagree, 2 being neutral, 3 being agree)
- People can get COVID-19 from spending time in the same room as an infected person (0 disagree, 1 agree)
- COVID-19 can be dangerous to all age groups (0 disagree, 1 agree)

The information score was constructed by adding together all these variables (the lowest score being 3, the highest being 11). The inter-item correlation measured by Cronbach's alpha for these items was 0.7.

The variables used to create the misinformation score are as follow:

- Lemon and alcohol can be used as sanitizers against COVID-19 (0 disagree, 1 agree)
- Africans are immune to COVID-19 (0 disagree, 1 agree)
- COVID-19 does not affect children (0 disagree, 1 agree)
- COVID-19 cannot survive in warm weather (0 disagree, 1 agree)
- COVID-19 is just the common flu (0 disagree, 1 agree)
- Local herbs can be used to treat COVID-19 patients (0 disagree, 1 agree)
- People with a strong immune system do not need to work about COVID-19 (0 disagree, 1 agree)
- COVID-19 does not exist, it is a lie (0 disagree, 1 agree)
- Taking alcohol can make someone immune to COVID-19 (0 disagree, 1 agree)

The misinformation score was constructed by adding together these variables (the lowest score being 0, the highest being 9). The inter-item correlation measured by the Kunder-Richardson coefficient was 0.6.

Appendix II. Logistic regression and marginal probability tables

Variable	OR (95 %CI)
Refugee Status * Geography (Ref: National - Urban)	
Refugee - Camp	0.36 (−0.95,1.68)
Refugee - Urban	0.39 (−0.81,1.58)
National - Rural	−0.26 (−0.98,0.47)
Month Number	−0.27 (−0.39,−0.15)
Refugee/Geography * Month Number	
Refugee - Camp	−0.19 (−0.36,−0.02)
Refugee - Urban	−0.04 (−0.36,0.27)
National - Rural	0.04 (−0.1,0.19)
Gender (Female)	−0.02 (−0.39,0.35)
Age (Centered)	−0.01 (−0.02,0.01)
Education beyond Primary Level	−0.37 (−0.81,0.06)
Lives with Somebody who had Symptoms	−0.38 (−2.73,1.96)
Lives with Somebody who had Symptoms * Month Number	−0.55 (−1.1,0)
Had Symptoms in past 14 days	−0.74 (−1.59,0.1)
Had symptoms in past 14 days * Month Number	0.4 (0.24,0.56)
Washes hands more than they used to	−1.04 (−1.65,−0.43)
Trusts Government in responding to COVID-19 (Ref: Agree)	
Disagree	1.2 (0.66,1.74)
Neutral	0.91 (0.49,1.32)
Information Score (Centered)	−0.01 (−0.21,0.19)
Misinformation Score (Centered)	0.37 (0.1,0.64)
Misinformation Score * Month Number	−0.1 (−0.18,−0.02)
Constant	−0.07 (−1,0.86)

Variable	Marginal Probability (95 %CI)
Geography (Ref: National - Urban)	
Refugee - Camp	−0.03(−0.14,0.08)
Refugee - Urban	0.03(−0.06,0.12)
National - Rural	−0.01(−0.05,0.03)
Month Number	−0.02(−0.03,−0.01)
Gender (Female)	0(−0.04,0.04)
Age (Centered)	0(0,0)
Education Beyond Primary Level	−0.04(−0.09,0.01)
Lives with Somebody who Had Symptoms	−0.14(−0.19,−0.09)
Had Symptoms in past 14 days	0.11(0.05,0.17)
Washes hands more than they use to	−0.11(−0.18,−0.05)
Trusts Government in responding to COVID-19 (Ref: Agree)	
Disagree	0.15(0.07,0.22)
Neutral	0.1(0.05,0.15)
Information Score (Centered)	0(−0.02,0.02)
Misinformation Score (Centered)	0(−0.01,0.02)

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