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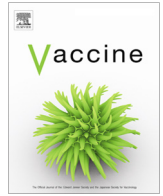
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# Health care worker vaccination against Ebola: Vaccine acceptance and employment duration in Sierra Leone



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## ABSTRACT

Health care workers (HCW) are at high risk of Ebola virus disease (EVD) infection during epidemics and may contribute to onward transmission, and therefore HCW-targeted prophylactic vaccination strategies are being considered as interventions. To assess the feasibility of preventive HCW vaccination, we conducted a pilot survey on staff turnover and vaccine acceptance amongst 305 HCW in Freetown and Kambia districts of Sierra Leone.

Multivariable logistic regression demonstrated which demographic and behavioural factors were associated with acceptance of a hypothetical new vaccine. We quantified the duration of employment of HCW, and used multivariable gamma regression to detect associations with duration of employment in current or any health care position. Finally, we simulated populations of HCW, to determine the likely future immunisation coverage amongst HCW based on our estimates of vaccine acceptance and employment duration.

Most HCW we surveyed had a positive opinion of EVD vaccination (76.3%). We found that being a volunteer HCW (vs being on the government payroll) was associated with increased vaccine acceptance. We found that HCW have stable employment, with a mean duration of employment in the health sector of 10.9 years (median 8.0 years). Older age and being on the government payroll (vs volunteer HCW) were associated with a longer duration of employment in the health sector. Assuming a single vaccine campaign, with 76.3% vaccine acceptance, 100% vaccine efficacy and no waning of vaccine-induced protection, immunisation coverage was sustained over 50% until 6 years after a vaccination campaign. If vaccine-induced immunity wanes at 10% per year, then the immunisation coverage among HCW would fall below 50% after 3 years.

Vaccinating HCW against EVD could be feasible as employment appeared stable and vaccine acceptance high. However, even with high vaccine efficacy and long-lasting immunity, repeated campaigns or vaccination at employment start may be necessary to maintain high coverage.

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## 1. Introduction

Health care workers (HCW) are at high risk of infection during Ebola virus disease (EVD) outbreaks [1], and may enhance transmission due to high transmission rates [2]. For this reason, HCW-targeted vaccination strategies are being considered for outbreak control [3].

There are several candidate vaccines under evaluation, with only one (rVSV-ZEBOV) that has been shown to be effective based on a phase III trial [4]. This vaccine has been used in outbreaks for control [5], including reactive vaccination of HCW [6]. Therefore, there is a need to understand the likely contexts in which EVD vaccines could be used.

The potential effectiveness of prophylactic HCW-targeted vaccination is partially determined by the coverage achieved during vaccination campaigns, and the rate of attrition and turnover of vaccinated staff. There is currently little data on the likely acceptability of vaccination in HCW [7] especially in previously-affected

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countries, although there is evidence of high acceptability among community members [8–10]. The dynamics of the health care workforce in Ebola-affected countries is unknown. Evidence from other parts of sub-Saharan Africa find high levels of turnover and quitting intention [11,12]. Analysis of routine data from the HCW payroll system in Sierra Leone revealed an overall annual attrition rate of about 5% between 2005 and 2011 [13].

To quantify future vaccine protection, especially if vaccine-induced immunity may wane, there is a need to determine vaccine acceptance among HCW and the effect of staff turnover on achievable immunisation coverage. We conducted a pilot survey of HCW in two districts in Sierra Leone to determine their attitudes to EVD vaccination, duration in their current position, longevity in the health care workforce, and to determine demographic associations with these factors.

The health system in Sierra Leone is largely public, where the Ministry of Health and Sanitation (MOHS) employs almost 10,000 people on its payroll system and around 9000 more informally as ‘volunteers’ [14]. There are some private and Non-Governmental Organisation (NGO) health facilities, which are not included in these figures. HCW on the government payroll receive an official salary and can be posted to other health facilities whereas ‘volunteers’ remain at their original health facility and may only receive informal payments, for instance from user fees. The health system is pyramidal, with a large number of peripheral health units (PHU) providing primary care, 21 (district) hospitals providing secondary care, and three referral hospitals for tertiary care [15]. The health system was weakened by the civil war and recent Ebola outbreak, although there are efforts being made to reach staffing requirements [15].

## 2. Methods

### 2.1. Study design

We undertook a pilot cross-sectional survey of HCW in Free-town and Kambia district, Sierra Leone from June–July 2018. Since this was a pilot study, we recruited a convenience sample of medical personnel providing care within health facilities (doctors, midwives, nurses, health aides, community health officers), health facility support staff (administrative, cleaners, porters, drivers), allied health professionals (pharmacists, laboratory workers) and community health workers. After initial local approval from the Community Health Officer (CHO), the data collectors approached potential respondents by explaining the research purpose. The first author and two trained research assistants experienced in health research in Sierra Leone conducted the survey. All HCW at visited health facilities were invited to take part if they fulfilled the following criteria: being at least 18 years old and working at this health facility or as a community health worker affiliated with this health facility. We did not limit our sample to Sierra Leone citizens, as we aimed to survey all HCW at health facilities, irrespective of their origin. Consequences for refusal were minimized by insisting that the survey was voluntary. As CHOs were generally supportive of the project, some HCW could have felt pressured to participate. For this pilot study, we did not perform a sample size calculation, nor calculate refusal rates, but we aimed to survey in urban and rural districts, in a range of health facilities, and across different HCW occupational cadres.

### 2.2. Survey questions

We designed an interviewer-administered, tablet-based questionnaire in OpenDataKit [16]. Participants could be interviewed and answer in English or Sierra Leone Krio, a widely spoken

language in Sierra Leone, and were interviewed by two teams of two interviewers, where one interviewer was present throughout. The 26 close-ended questions took approximately 10 min to complete. The questionnaire included five sections: general information, turnover of health care workers and occupational risk, vaccine acceptance, experience of the Ebola outbreak, and socioeconomic information (Supplementary Section 6). Vaccine sentiment was assessed using scenario questions designed to elicit accurate sentiment [17–19].

### 2.3. Ethical approval

Ethical approval for this study was granted by the Sierra Leone Ethical and Scientific Review Committee and by the London School of Hygiene & Tropical Medicine ethics committee (Reference: 15482). Moreover, approval was sought from local authorities (district medical officer, principal medical officer). All those who agreed to participate gave informed consent.

### 2.4. Recoding of variables

We used the two vaccination scenario questions about a new EVD vaccine to create a variable called “vaccination opinion”, with three categories: a positive opinion on Ebola vaccination, unsure (would like to observe on others first, or do not know), or a negative opinion on vaccination. We coded responses that were unsure and negative as negative vaccine sentiment in statistical analysis of vaccine sentiment. We tested the effect of combining unsure with positive or negative opinion in the immunisation coverage model.

We calculated duration of employment either from the date of employment or the age at employment, depending on which the participant provided. In the first case, the ‘duration of employment in the health sector’ was the difference between the last survey date (July 8th 2018) and the reported starting date of employment. In the second, it was the difference between the current age and the reported age at start of employment. The variable ‘duration of employment in the current job’ was generated using the same approach as for the duration of employment in the health sector. Where the duration of employment in the current job exceeded the duration of employment in the health sector, the duration in the current job was recoded to be equal to the total length of employment in the health sector. Further minor recoding is described in Supplementary Section 1.

### 2.5. Comparison to Sierra Leone workforce

To determine whether the study sample was representative of the population of HCW in Sierra Leone, we compared sample characteristics to data from the Sierra Leone Human Resources for Health Country Profile [14]. Detailed data were only available for HCW on the government payroll, so we were only able to compare those HCW on the payroll in our sample.

### 2.6. Analysis of survey responses

We used logistic regression for univariable associations between positive vaccine opinion and each of the explanatory variables: gender, age group, urban or rural location, profession, income group, full time employment, payroll status (volunteer or on government payroll), and type of health facility. We found that education level was highly correlated with income and professional cadre and therefore we excluded it from the analysis. We first fitted univariable models to investigate likely associations, before fitting a multivariable logistic regression with stepwise model selection using the Akaike Information Criterion [20,21] to ensure that we were not including correlated explanatory

variables. We determined the effect of interactions between key variables (Supplementary Section 3).

As duration of employment was strictly positive, we used a gamma distribution to model the duration of employment in the current job and the total duration of employment as a HCW. We fitted a multivariable gamma regression model to determine which factors were associated with employment durations. We considered the same variables as for vaccine opinion. We used an inverse link function, so a negative coefficient corresponds to an increase in duration [22]. To transform these coefficients to odds ratios, we simulated durations of employment from the fitted model for the baseline model and all significant variables. The odds ratio is then the mean and quantiles of the ratio of simulated expectations.

### 2.7. Simulated vaccination coverage

To quantify likely effective immunisation coverage we built a model based on the level of vaccine acceptance and HCW employment duration found in our analyses, combined with hypothetical values for vaccine efficacy and waning of vaccine-induced protection. We assumed either that all HCW with a positive opinion on vaccination would accept vaccination or that all HCW with a positive opinion or unsure would accept vaccination. Uncertainty in the acceptance value was included by sampling from a beta distribution whose shape parameters have a mean that matches the respective acceptance proportion,  $a_j$ , for the number of participants surveyed. The proportion of HCW leaving employment each year was estimated as above, including uncertainty.

We simulated the effect of 100% or 75% initial vaccine efficacy, and to determine the impact of waning of vaccine-induced protection, we assumed either 0% (no waning) or 10% (moderate waning) per year. The model for immunisation coverage is therefore

$$C(t) = aE(1 - w)^t q(t; \alpha, \beta)$$

where  $q(t; \alpha, \beta)$  is the area to the right of  $t$  (in years) in a Gamma distribution with parameters drawn from the estimates of  $\alpha, \beta$  from model of HCW career length,  $w$  is the waning parameter,  $a \sim B(a_j n, (1 - a_j) n)$  is the acceptance rate of vaccination and  $E$  is the efficacy of the vaccine immediately following immunisation (parameter values given in Supplementary Section 5).

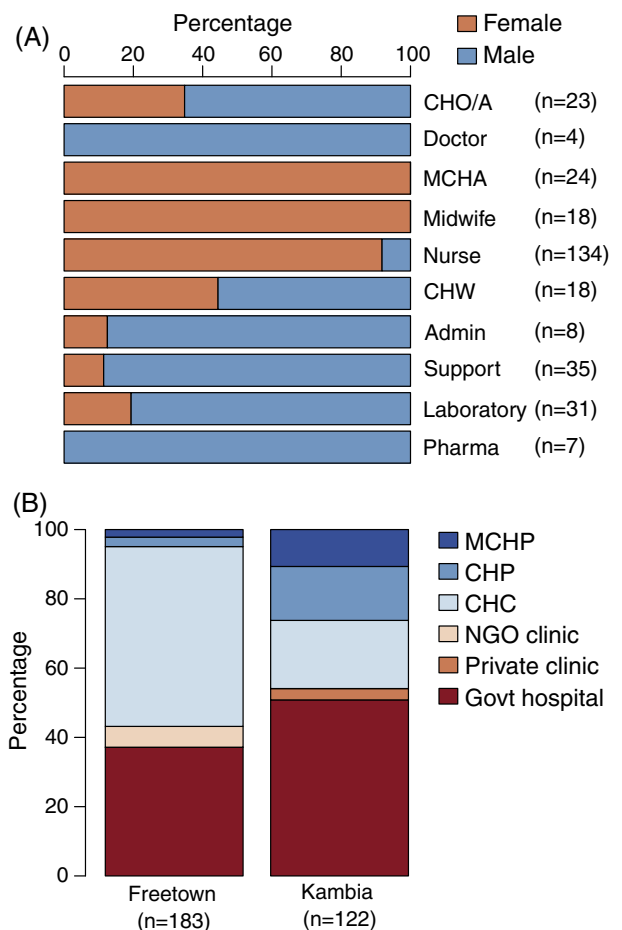
## 3. Results

### 3.1. Description of study sample

We surveyed 305 HCW (183 (60.0%) in Freetown, 122 (40.0%) in Kambia district), across ten different HCW cadres (Fig. 1). 195 (63.9%) were female, and 211 (69.4%) were between 25 and 44 years old (Table 1). Only 15 (4.9%) HCW in this convenience sample worked outside government health facilities in private or NGO clinics.

The type of health facility differed by district (Fig. 1B). In Freetown, the majority of HCW surveyed worked in community health centres (CHC) (51.9%) whereas few HCW worked in smaller PHUs (4.9% in total: 2.7% in Community Health Posts (CHP), 2.2% in Maternal and Child Health Posts (MCHP)) and 37.2% worked in government hospitals. In Kambia, most HCW surveyed worked in the government hospital (50.8%), whereas others were distributed between the different PHU types (CHC 19.7%, CHP 15.6%, MCHP 10.7%).

Within the sample there were marked gender differences by profession, with a higher proportion of female nurses, midwives, and maternal and child health aides (MCHA) and a higher proportion of male doctors, community health officers (CHO), laboratory



**Fig. 1.** Characteristics of HCW in the surveyed population. (A) Gender composition by profession; (B) Health-centre type by district. Freetown is an urban district, and Kambia is rural. CHO/A: Community health officer/assistant; MCHA: Maternal and Child Health Aide; CHW: Community Health worker; Lab: Lab worker; Pharma: Pharmacist; MCHP: Maternal and Child Health Post; CHP: Community Health Post, CHC: Community Health Center, Govt hospital: Government Hospital.

technicians, pharmacists, community health workers (CHW), administrative personnel, and support staff (Fig. 1A).

### 3.2. Comparison to Sierra Leone workforce

The sampled population of HCW on the payroll was similar to the Sierra Leone workforce in terms of gender (60.3% vs. 62.0%,  $p = 0.55$  ( $\chi^2$  test)) and age ( $p = 0.38$ , ( $\chi^2$  test)). However, we oversampled HCW working in CHCs compared with the Sierra Leone workforce, whereas HCW working in other health facility types were under sampled (Supplementary Section 2). Moreover, laboratory workers, midwives and CHOs were oversampled whereas MCHAs, and administrative and support staff were under sampled ( $p < 0.01$  ( $\chi^2$  test), Supplemental table 1).

Differences in gender and profession in our sample largely reflect the proportions of HCW in Sierra Leone [14].

### 3.3. Vaccine acceptance

232 study participants (76.3%) had a positive opinion on Ebola vaccination, while 61 (20.1%) were unsure (Table 1). Amongst those unsure, 41 (13.5%) had no definite opinion on Ebola vaccination while 20 (6.6%) would like to observe the vaccine on others first.

**Table 1**

Sample characteristics. CHP/MCHP: Community Health Post/Maternal and Child Health Post; CHW: Community Health Worker; HCW: Health care worker, NGO: Non-governmental Organisation. Ebola contact is yes if the individual knows anyone who had Ebola during the 2014–15 epidemic (question D1 (Supplement)).

Variable	Level	Number	%
Gender	Female	195	63.9
	Male	110	36.1
Age (1 missing)	18–24	15	4.9
	25–34	109	35.9
	35–44	102	33.6
	45–54	54	17.8
	55+	24	7.9
District	Freetown	183	60.0
	Kambia	122	40.0
Ethnicity (1 missing)	Temne	89	29.3
	Mende	87	28.6
	Limba	46	15.1
	Mandingo	20	6.6
	Fula	12	3.9
	Krio	12	3.9
	Susu	9	3.0
	Kono	8	2.6
Religion	Other/multiple	21	6.9
	Christian	167	54.8
Education	Muslim	138	45.2
	Did not complete secondary	34	11.1
	Completed secondary	136	44.6
Location	Tertiary	135	44.3
	Rural	54	17.7
Income (10 missing)	Urban	251	82.3
	Low	94	30.8
	Medium	100	32.8
Health facility type	High	101	33.1
	Government hospital	130	42.6
	Community Health Centre	119	39.0
	CHP/MCHP	41	13.4
Working full time	Private/NGO	15	4.9
	Full-time	284	93.1
	Part-time/casual	21	6.9
On payroll (1 missing)	Payroll	179	58.9
	Volunteer	125	41.1
Profession group (3 missing)	Medical care in health facility	203	67.2
	CHW	18	6.0
	Support staff in health facility	43	14.2
	Lab worker/pharmacist	38	12.6
Number health centres worked at	1	81	26.6
	2	81	26.6
	3–5	90	29.5
	5+	53	17.4
	No	270	88.5
Break in HC work (1 missing)	Yes (<6 months)	24	7.9
	Yes (>6months)	10	3.3
	No	73	23.9
Ebola contact	Yes	232	76.1
	No	83	27.2
Worked as HCW during the W African Ebola epidemic	No	83	27.2
	Yes	222	72.8
Vaccination opinion (1 missing)	Positive	232	76.3
	Unsure	61	20.1
	Negative	11	3.6

In the univariable analysis, the following were associated with having a positive opinion on vaccination: having secondary-only education (Odds Ratio (OR): 2.33, 95% Confidence Interval (CI): 0.98, 5.38), having a medium level of income (OR: 0.37, CI: 0.18, 0.72) and being on the government payroll (OR: 2.30, CI: 1.30, 4.22) (Table 2). In the multivariable model before model selection, only payroll status (being a volunteer) was significantly associated with positive opinion, with an OR of 2.44 (CI: 1.14, 5.45). After stepwise selection, all variables except payroll status were removed, and payroll status remained associated with positive

opinion (OR 2.39, CI: 1.35, 4.39). There was a small change in OR between the univariable and multivariable models caused by a difference in missingness between the payroll status alone and the whole data frame.

We found an interaction between payroll status and health care centre type but did not include this in the full model because the facility types where sentiment in volunteers was not higher than in payroll staff had small numbers of participants and overlapping confidence intervals (Supplementary Section 3).

### 3.4. HCW turnover

We found that 284 (93.1%) of HCW reported working full-time, however, only 179 (58.9%) reported being on the government payroll system. Surveyed HCW reported having been in their current positions for 5.97 years on average (median = 4.19) and had an average total career length of 10.9 years (median = 8 years) (Supplementary Section 3).

The majority (224, 73.4%) thought it was very likely that they would still work at their current health facility in 6 months' time, while only 36 (11.8%) considered it as very unlikely. One third (106, 34.7%) considered it as very likely they would work at their current facility for at least two years, and only a minority (59, 19.3%) considered it very unlikely that they would be working at their current facility in two years' time.

In multivariable regression, we found that length of career as a HCW was associated with age and payroll status, such that not being on the payroll was associated with a shorter duration as a HCW, and higher age groups associated with a longer duration as a HCW (Table 3). The mean duration of employment as a HCW of those on the payroll was 14.2 years as compared to 6.0 years for volunteers (see Fig. 2).

In multivariable regression of the duration in the current job, we found that age and payroll status were also associated with the duration of employment in the current job, and additionally, living in an urban environment and being male were associated with an increase in the duration of employment in the current job (Table 3).

### 3.5. Implications for vaccine protection

Assuming a single vaccination campaign, high vaccine acceptance (96.4%, positive sentiment and unsure), 100% vaccine efficacy, and no waning of vaccine-induced immunity, the fraction of protected HCW would be expected to fall below 50% during the eighth year (Fig. 3A). With vaccine waning of 10% per year, effective immunisation coverage would fall below 50% during the fourth year. If acceptance were lower (76.3%, positive sentiment only) the effective fraction of HCW protected would fall below 50% during the sixth year with no waning, and the third year if there were 10% waning per year (Fig. 3C).

Assuming lower vaccine efficacy (75%), and the same high and low acceptance and 0% or 10% per year waning, effective immunisation protection drops below 50% after one to five years (Fig. 3B & D). This model could be easily incorporated into models of EVD transmission to model impact of vaccinating HCW.

## 4. Discussion

This study has contributed to the evidence base for implementation of HCW-targeted EVD vaccination strategies. We provide evidence from a pilot survey of HCW on the likely acceptance of an EVD vaccine in a recently infected country. We have also generated new findings on the turnover of HCW in these areas, which we found is associated with age, payroll status, gender, and an urban

**Table 2**

Association with vaccination opinion for the univariable models, showing the baseline level of each covariate, the corresponding baseline probability, and the odds ratio (and 95% CI and p value) for each other level of that covariate. CHC: Community Health Center, CHP/MCHP: Community Health Post/Maternal and Child Health Post; CHW: Community Health Worker, NGO: Non-Governmental Organisation.

Covariate	Baseline probability (95% CI)	Level	Odds ratio (95% CI)	p-value
Age	18–24: 0.87 (0.64, 0.98)	25–34	0.58 (0.09, 2.28)	0.487
		35–44	0.44 (0.07, 1.75)	0.306
		45–54	0.40 (0.06, 1.68)	0.263
		55+	0.46 (0.06, 2.38)	0.387
District	Freetown: 0.79 (0.73, 0.85)	Kambia	0.68 (0.40, 1.17)	0.161
Education	No Secondary: 0.68 (0.51, 0.82)	Secondary	2.33 (0.98, 5.38)	0.050
		Tertiary	1.22 (0.53, 2.70)	0.629
Ethnicity	Temne: 0.74 (0.64, 0.82)	Mende	0.82 (0.42, 1.58)	0.550
		Limba	2.32 (0.92, 6.73)	0.092
		Fula	1.74 (0.42, 11.89)	0.494
		Mandingo	1.39 (0.45, 5.24)	0.586
		Kono	0.35 (0.08, 1.58)	0.158
		Krio	0.70 (0.20, 2.81)	0.584
		Susu	2.79 (0.47, 53.15)	0.346
		Other/multiple	3.14 (0.82, 20.69)	0.145
		Full-time	3.12 (0.88, 19.91)	0.132
		CHC	1.71 (0.95, 3.12)	0.077
		CHP/MCHP	1.47 (0.66, 3.53)	0.364
Private/NGO	2.68 (0.70, 17.70)	0.208		
Income group	Low: 0.84 (0.76, 0.90)	Medium	0.37 (0.18, 0.72)	0.005
		High	0.76 (0.36, 1.58)	0.465
Payroll status	On payroll: 0.71 (0.64, 0.77)	Volunteer	2.30 (1.30, 4.22)	0.005
Profession group	Medical care in health facility: 0.76 (0.70, 0.82)	CHW	1.56 (0.49, 6.93)	0.497
		Support staff	0.65 (0.32, 1.35)	0.231
		Lab worker/pharmacist	1.38 (0.60, 3.59)	0.474
Religion	Christian: 0.76 (0.69, 0.82)	Muslim	1.05 (0.62, 1.80)	0.853
Sex	Female: 0.77 (0.71, 0.82)	Male	0.93 (0.54, 1.62)	0.790
Urban/rural	Rural: 0.78 (0.66, 0.87)	Urban	0.90 (0.43, 1.78)	0.781

**Table 3**

Odds ratios and 95% confidence intervals from Gamma regression models of employment duration. Untransformed coefficients are given in Supplementary Section 4.

Variable	Level	As a health care worker	In current job
		OR (95% CI)	OR (95% CI)
Age Group	18–24	Reference	Reference
	25–34	1.91 (1.12, 2.70)	1.45 (0.86, 2.11)
	35–44	3.45 (1.93, 4.85)	2.03 (1.21, 2.93)
	45–54	5.56 (3.21, 7.93)	2.24 (1.31, 3.28)
	55+	7.56 (4.17, 11.38)	2.85 (1.63, 4.43)
Payroll status	On Payroll	Reference	Reference
	Volunteer	0.84 (0.73, 0.91)	0.89 (0.78, 0.97)
Gender	Female	–	Reference
	Male	–	1.07 (1.00, 1.16)
Location	Rural	–	Reference
	Urban	–	1.33 (1.14, 1.72)

location. We used our findings to quantify the effective vaccine coverage through time if prophylactic HCW-targeted campaigns were used.

We found that likely acceptance of an EVD vaccine was high among HCW in Sierra Leone. Being a volunteer worker (rather than on the government payroll) was associated with an increase in vaccine acceptance in the multivariable model, but acceptance was high for all groups surveyed. Our findings correspond to findings from another Ebola-affected country (Guinea), where self-reported vaccine acceptance was high in the general population [8]. They also confirm findings of high levels of EVD vaccine approval in Nigeria among HCW [7]. In our survey, we found no association between vaccine acceptance and experience of EVD cases, defined as knowing someone who had EVD or having worked as a HCW during the West African epidemic.

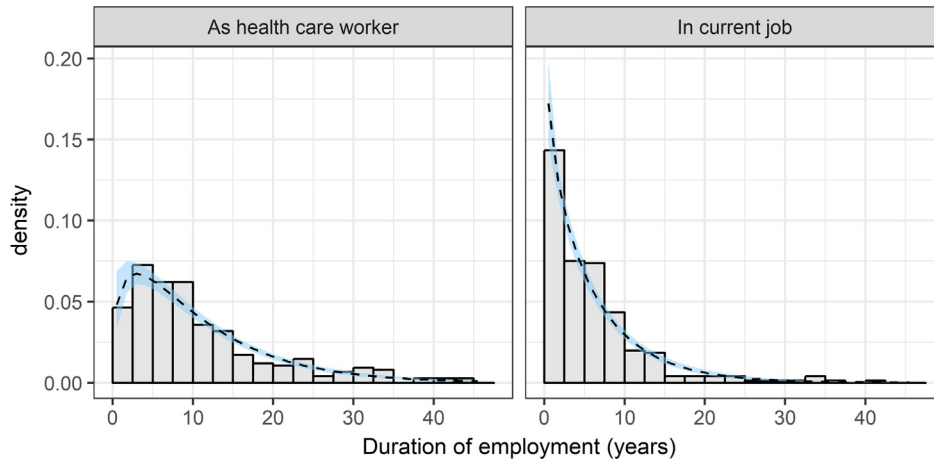
The employment turnover observed in our study corresponds to government surveys of HCW on payroll in Sierra Leone, where the annual attrition rate has been estimated around 5% [13]. We found that the turnover of HCW was sufficiently low to maintain vaccina-

tion coverage above 50% among HCW for several years after a vaccination campaign, especially for scenarios of high vaccine efficacy and low waning immunity. However, depending on the level of coverage required, it might be necessary to adapt the vaccination strategy, for instance through regular campaigns or vaccination upon employment.

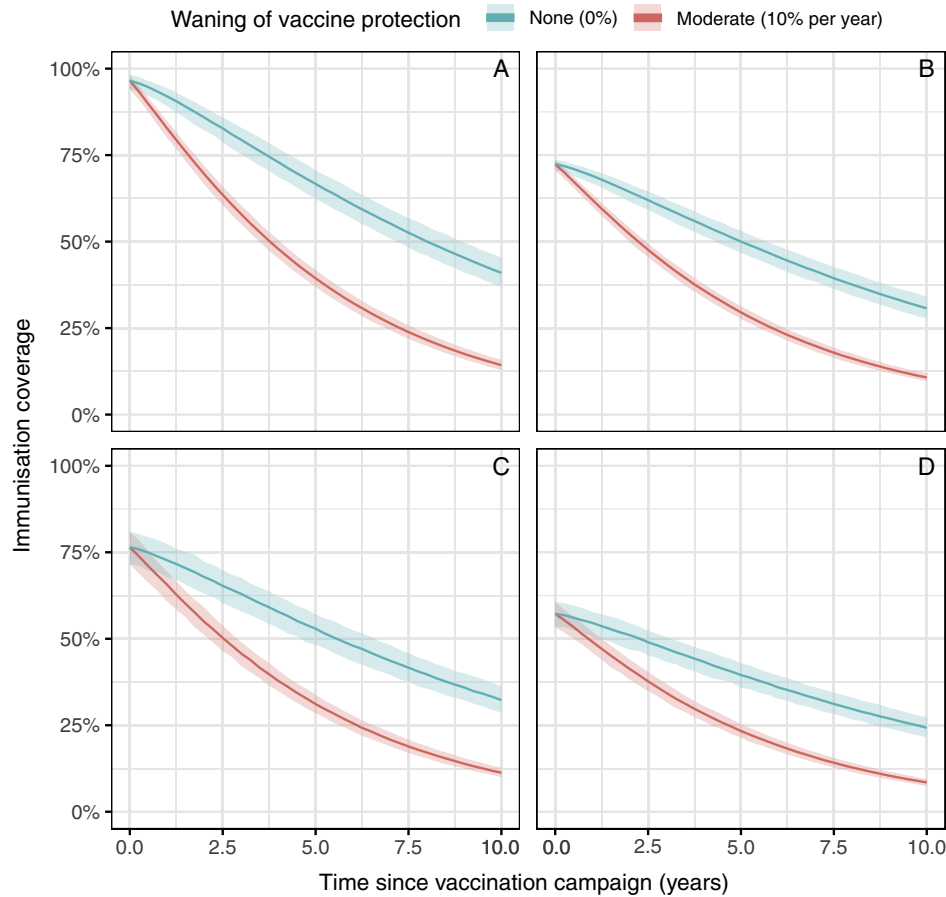
Finally, by providing parameter estimates of turnover and vaccine acceptance with a quantification of uncertainty, our results allow for a straightforward link to modelling and evaluation of vaccination strategies. It enables incorporation of the vaccination coverage model into existing transmission models of EVD control [2].

We sampled HCW of different cadres in a range of health facility types, in both urban and rural settings, which increases confidence in the generalisability of our findings despite using a convenience sample. However, Sierra Leone is a diverse country, and there could be local variation in vaccine acceptance or in the dynamics of employment. We did not detect any differences by religion or ethnic group, but we did not comprehensively survey these groups in Sierra Leone, and this pilot study was not powered to detect these effects. In Kambia district, vaccine acceptance could also be affected by the presence of the EBOVAC project, which aims to evaluate immunogenicity of a prime-boost EVD vaccine (AD26.ZEBOV/MVA-BN-Filo vaccine by Janssen) [23]. Survey participants may have interacted with the research program in this region and may have altered their responses if they associated the survey with the EBOVAC project. It is unlikely that this would result in differential social desirability bias between payroll and volunteer HCW, as both cadres would likely favour employment with the project.

Our questionnaire was developed in collaboration with social scientists with in-country experience of the Sierra Leone health system. Although we used modern methods to elicit Ebola vaccine opinion, the sentiments we find may not correspond to actual vaccine uptake, since no licensed vaccine is available, and therefore the vignettes used to elicit vaccine sentiment are not validated.



**Fig. 2.** Distributions of durations of employment. Fitted gamma density functions are shown as a dotted line, with 95% simulation-based confidence intervals. The fitted gamma distributions give shape and rate parameters, of (shape = 1.35 (95%CI 1.16, 1.55), rate = 0.12 (0.10, 0.15)) for career as HCW and 0.88 (0.76, 1.01) and 0.15 (0.12, 0.18) for duration of current job.



**Fig. 3.** Effective immunisation coverage after a single vaccination campaign. (A) vaccine acceptance 96.4%, vaccine efficacy 100%; (B) vaccine acceptance 96.4%, vaccine efficacy 75%; (C) vaccine acceptance 76.3%, vaccine efficacy 100%; (D) vaccine acceptance 76.3%, vaccine efficacy 75%.

We surveyed HCW in Freetown and Kambia, two areas that were affected during the 2014–16 epidemic. Therefore, it is possible that HCW in these regions had more experience of EVD, information, or differences in risk perception, compared with less affected areas, which could increase positive attitudes toward vaccination. Further work could survey areas with less experience of EVD to evaluate this.

Although we provide evidence that the sample is representative in terms of age and gender, we used convenience sampling. There is limited information on HCW employment from Sierra Leone, so comparison of our sample population to all HCW is only possible on few variables, and we oversampled some health facility types and professions. Additionally, our study had a high proportion of public health facilities, and private clinics and individual

practitioners may have different vaccine acceptance and employment dynamics. We were not able to sample all health-related professions (e.g. environmental health worker, dentist, ambulance driver) and these groups may exhibit different characteristics. For future surveys we anticipate that stratifying HCW by profession to look at employment duration would be a useful extension to the simulation of vaccine coverage, but was not possible to weight the data to correct for undersampling of these profession groups, so caution is needed when generalising the findings. In addition, a larger sample with a robust sampling method may give insight into other factors associated with vaccine acceptance, beyond those found here.

Employment duration and turnover were assessed based on a cross sectional survey of current employees. We assumed that these durations corresponded to current and future HCW employment durations. Cross-sectional surveys are affected by length time bias, where there is a higher chance of interviewing HCW with longer employment duration. Our study may therefore overestimate the duration of employment; however, we find a good fit to an exponential distribution, which suggests this bias may not be pronounced. Sampling only current HCW also means we cannot gain understanding of the vaccine sentiment of those who have recently changed careers. It is possible those individuals may have different vaccine sentiments.

Recruitment and employment patterns in the health system may have been affected by the civil war until 2002 [24] and by the Ebola outbreak [25,26]. Similarly, the recent introduction of the Free Health Care Initiative [27] and other policy changes could affect employment patterns in the future.

We found a positive association with a moderate level of income and vaccine acceptance. Speculative reasons may be that HCW at moderate pay have higher exposure to patients, which affects risk perception. This finding warrants further investigation to determine if it is a true association, and how risk perception relates to vaccine acceptance.

In addition to these limitations, the effect of payroll or volunteer status is specific to the Sierra Leone health system. HCW on the government payroll and volunteers carry out similar duties, despite the latter not yet being officially employed. HCW on payroll can be posted to another health facility in the country whereas volunteers would normally stay at the same facility until official employment. In addition, there are students who carry out short-term traineeships in health facilities. Students normally carry out several traineeships during their studies at different health facilities. For future vaccination planning, targeting payroll-only or all HCW would affect effective immunisation coverage, although further exploration of why volunteer status was associated with increased vaccine acceptance, and if there is any difference in risk or risk perception, is needed.

## 5. Conclusion

This survey provides evidence on the feasibility of HCW-targeted prophylactic EVD vaccination strategies. We found that vaccine acceptance was high, and HCW turnover sufficiently low to sustain vaccination coverage above 50% for several years after a vaccine campaign. These results could be used for more detailed models of EVD transmission to assess the potential impact of vaccinating HCW.

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## Author contributions

RME conceived the study. MJ, RME, WJE, HR, TM designed the questionnaire. MJ, SC analysed the data. MJ and RME wrote the first draft of the paper. All authors interpreted the results and contributed to the final manuscript.

## Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2018.12.060>.

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