Dear Editor,

A recent paper by Etard et al highlights how clustering of Ebola exposures around a few cases, and overdispersion of contacts per case, leads to super-spreader events and epidemic propagation[1]. Based on this evidence and that seen with SARS-Cov-2[2], they suggest that targeting epidemic screening and communication control strategies in low resource settings may be beneficial.

Here, we summarise a study we conducted to assess the success of contact tracing in relation to different characteristics of cases and contacts. To our knowledge, the association of a contact's characteristics with their likelihood of being successfully traced during a pandemic has not previously been assessed.

We analysed data collected during the 2014-2016 West African Ebola epidemic to identify case and contact characteristics associated with success of contact-tracing. Data were collected in the Ebola Contact Tracing proof-of-concept Study (ECTS) in Port Loko district, northern Sierra Leone, April-August 2015. The study aimed to design and evaluate the use of a mobile health (mHealth) app relative to paper-based contact-tracing[3]. We found that the app improved data completeness, storage, and accuracy, but that challenges in tracing remained.

We have subsequently further analysed the app-based data to investigate which case and contact characteristics were associated with successful mHealth contact-tracing. A total of 16 laboratory-confirmed Ebola virus disease (EVD) cases (one of whom was excluded from this analysis as they had no contacts), and two secret burial cases, were registered on the study app. From the 17 included cases, 646 contacts were identified and recorded on the app by the local case investigation team.

Successful contact tracing was defined as a contact being visited by a contact-tracer (CT), and an ECTS app form being completed daily from first contact with a CT throughout the remaining incubation-period. The association of successful tracing with Ebola case characteristics (age, sex and survival) and contact characteristics (age, sex, type of contact with the Ebola case, and urban/rural location) was investigated by estimating adjusted hazard ratios (aHR) using multivariable Cox regression, adjusted for clustering by case. Follow-up time was time between last contact with the Ebola case and first visit from a CT. For all non-traced contacts, follow-up time was set at 21-days (maximum incubation-period). The multivariable model was built by first fitting univariable models, including those variables with $p<0.05$ in an initial multivariable model, and retaining those independently associated with the outcome in a final multivariable model. Models were compared using the Likelihood Ratio test.

Of the 646 registered contacts, 365 (57%) were traced. The median age of cases was 29 years for both traced and non-traced groups. Those not traced were more likely to be contacts of male cases (n=173, 61.6%) than those traced (n=142; 38.9%). The median number of contacts per case was higher in the non-traced group (92 contacts vs 52 contacts). Non-traced contacts were older (median 24-years vs 19-years) and more likely to be male (n=157, 55.9% vs n=160, 43.8%) than the traced contacts. In the non-traced group, the most common form of contact was physical contact with the body (n=132, 47.0%) whereas in the traced group the most common form of contact was sharing a room with the case (n=139, 38.1%). A greater proportion of non-traced contacts than traced contacts lived in rural settings (n= 247, 87.9% vs n=95, 26.0%).

In the final multivariable Cox model, three factors were independently associated with contact tracing success. The case being female was positively associated with successful contact tracing (aHR 4.96; CI 1.55-15.90, p<0.01). The contact living in a rural as opposed to urban setting (aHR=0.04; CI 0.01–0.12, p<0.01) and the contact having direct contact with the Ebola-case, their personal items, or bodily fluids (Table 2) were negatively associated with successful tracing.

To our knowledge, this is the first study of its kind to utilise app-based data to examine factors affecting contact-tracing. Introduction of mHealth into the tracing process removes obstacles to tracing, such as large travel distances and poor transportation. However, this study shows additional issues associated with living in a rural environment that affect the likelihood of successful tracing, even once the travel barriers have been removed. Mode of contact with the Ebola case had a complex relationship with success of contact tracing. Those who had the closest contact with the case were twice as likely to be contact traced as those who had not had physical contact, but half as likely as those who had minor physical contact with the Ebola case. We hypothesise that there is an interaction between social factors such as stigma, personal perception of disease-risk, concerns regarding financial loss, and isolation at play[4].

Based on our findings, in future epidemics in low-resource settings, contact-tracing programs need to be designed with a strategy in mind for reaching those in rural locations, as well as contacts of specific case characteristics including those who are of male sex and the superspreaders described by Majra et al[2]. This must however, not be to the detriment of those currently being traced.

With the ongoing SARS-CoV2 pandemic, and increasing evidence of epidemics becoming more common, contact-tracing programmes are going to become more integral to maintaining normality and preventing the economic and societal damage seen when blanket restrictions are enforced. We recommend further qualitative research to understand whether our findings are generalisable, and to develop strategies to reach those who are harder to trace.

Acknowledgements:

The study received the support and would like to extend thanks to the Ministry of Health and Sanitation, the District Health Management Team (Port Loko), the Ebola Response Centre Teams at national and local levels in Sierra Leone, the WHO Freetown Office, WHO Port Loko Field Coordinators and Epidemiology support leads, the Surveillance Pillar, GOAL, Marie Stopes,UNFPA (Sierra Leone), CDC, the Republic of Sierra Leone Armed Forces (RSLAF) and Public Health England (PHE). We would also like to thank UNMEER for the donation of the study phones, IPA Sierra Leone staff, IMC staff and all the contact tracing coordinators and contact tracers that participated in this study and Rachel Miles from LSHTM for providing administrative support.

Funder:

This study was funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. The funder was not involved in the design, collection, analysis and interpretation of the data and writing of this manuscript. HAW received support in part from a grant from the

Medical Research Council (MRC) and the Department for International Development (DFID UK) under the MRC/DFID Concordat (K012126/1).

Availability of data and materials

The datasets analysed during the current study are available in the London School of Hygiene & Tropical Medicine data repository https://datacompass.lshtm.ac.uk/1069/

Ethics approval and consent to participate

The London School of Hygiene & Tropical Medicine Observational/Interventions Research Ethics Committee (reference 8749–01) and the Sierra Leone Ethics and Scientific Review Committee (SLESRC) approved this study. Written informed consent was obtained from eligible Contact Tracing Coordinators and Contact Tracers who consented to take part in the study. Consent was not required from individual Ebola contacts as the smartphone app mirrored the existing paper-based system that was in use for contact tracing throughout the country.

References

1. Etard JF, Touré A, Sow MS, et al. Heterogeneity of contact patterns with Ebola virus disease cases. *J Infect* 2021.
2. Majra D, Benson J, Pitts J, et al. SARS-CoV-2 (COVID-19) superspreader events. *J Infect* 2021; 82(1):36-40.
3. Danquah LO, Hasham N, MacFarlane M, et al. Use of a mobile application for Ebola contact tracing and monitoring in northern Sierra Leone: a proof-of-concept study. *BMC Infectious Diseases* 2019; 19(1):810.
4. Saurabh S, Prateek S. Role of contact tracing in containing the 2014 Ebola outbreak: a review. *Afr Health Sci* 2017; 17(1):225-236.

Table 1 Baseline characteristics of participants recorded on The Ebola Contact Tracing Study App and the distribution of these characteristics between successfully and unsuccessfully traced contacts.

	Contact tracing	
	Traced	**Not traced**
	N = 365	N = 281
Ebola Case Factors (17 cases: 15 laboratory confirmed; 2 secret burials)	n (%)*	n (%)*
Age of Ebola case (years), median (IQR)	29 (22, 29)	29 (24, 50)
Sex of Ebola case		
Male	142 (38.9%)	173 (61.6%)
Female	223 (61.1%)	108 (38.4%)
Status of Ebola case		
Dead	213 (58.4%)	174 (61.9%)
Alive	152 (41.6%)	107 (38.1%)
Number of contacts per Ebola case, median (IQR)	52 (24, 120)	92 (66, 112)
Ebola contact factors		
Age of Ebola contact (years) , median (IQR)	19 (5, 35)	24 (9, 36)
Sex of contact		
Male	160 (43.8%)	157 (55.9%)
Female	205 (56.2%)	124 (44.1%)
Type of contact with Ebola case**		
Touched the body fluids of the case	62 (17.0%)	11 (3.9%)
Had direct physical contact with the body of a case	108 (29.6%)	132 (47.0%)
Touched or shared the linen, clothes, or dishes/utensils of the case	56 (15.3%)	21 (7.5%)
Slept, ate or spent time in the same household or room as the case	139 (38.1%)	51 (18.2%)
Ebola contact location factors		
Level of development***		
Urban	270 (74.0%)	34 (12.1%)
Rural	95 (26.0%)	247 (87.9%)

* Percentage of those with complete data
** Each contact was assessed for the highest risk level of contact and only this level was recorded
*** Based on standardised categories developed for The Ebola Contact Tracing Study (3)

Table 2: Cox-regression shared frailty model showing the effect of Ebola Case and Contact factors on Hazard ratios of successful contact tracing over a 21-day follow-up period adjusted for clustering around cases.

Ebola case factors	**unadjusted hazard ratio**	**Confidence interval (95%)**	**p value**	**adjusted hazard ratio**	**confidence interval (95%)**	**p value**
Age of Ebola case (years)			<0.01			
	reference					
30-60	0.57	0.44-0.74				
Over 60	0.16	0.05-0.51				
Missing data	0.26	0.17-0.40				
Sex of Ebola case			<0.01			<0.01
Male	reference			reference		
Female	1.63	1.32-2.01		4.96	1.55-15.90	
Number of contacts per Ebola case (per 1 contact increase)	0.99	0.99-1.00	<0.01			
Mortality status of Ebola case			0.03			
dead	reference					
alive	1.26	1.02-1.55				
Ebola contact factors						
Age of Ebola contact (years)						
0-30	reference		<0.01			
30-60	0.81	0.63-1.03				
Over 60	0.87	0.57-1.32				
Sex of contact			<0.01			
Male	reference					
Female	1.35	1.09-1.65				
Type of contact with Ebola case**			<0.01			<0.01
Touched the body fluids of the case (blood, vomit, saliva, urine faeces)	0.81	0.60-1.10		0.57	0.37-0.88	
Had direct physical contact with the body of a case (alive or dead)	0.38	0.30-0.49		0.44	0.30-0.65	
Touched or shared the linen, clothes, or dishes/utensils of the case	0.58	0.42-0.79		0.21	0.13-0.32	
Slept, ate or spent time in the same household or room as the case	reference			reference		
Ebola contact location factors						
Level of development ***			<0.01			<0.01
urban	reference			reference		
rural	0.17	0.14-0.22		0.04	0.01-0.12	

** Each contact was assessed for the highest risk level of contact and only this level was recorded
*** Based on standardised categories developed for The Ebola Contact Tracing Study (3)