Age structure and mixing patterns

Session 7

Outline

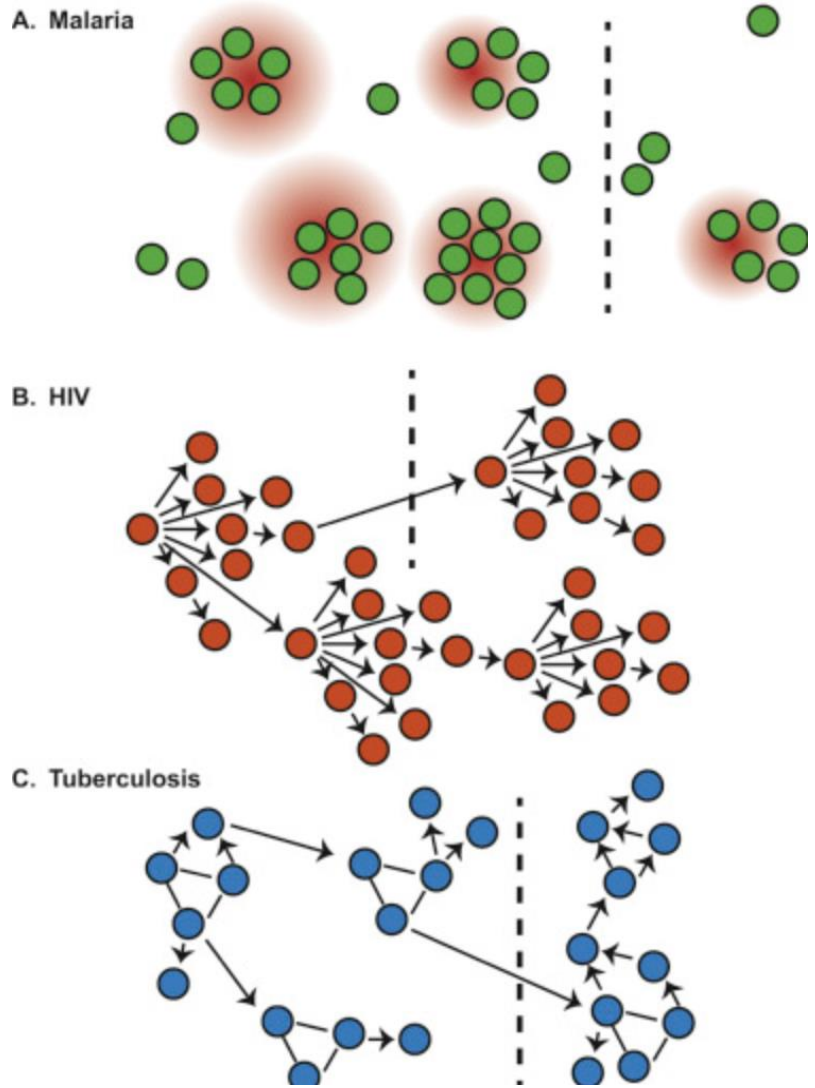
1. Effective 'contacts' and why they matter
2. How to measure contact?
3. The GlobalMix study

Respiratory and enteric infections

Centrality of **human** behavior

Direct, person-to-person transmission

- contacts ubiquitous
- communities, households

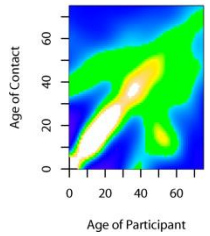


Childs et al. 2015

Social contact data is a key input into transmission models

S = susceptible
I = infected
R = recovered

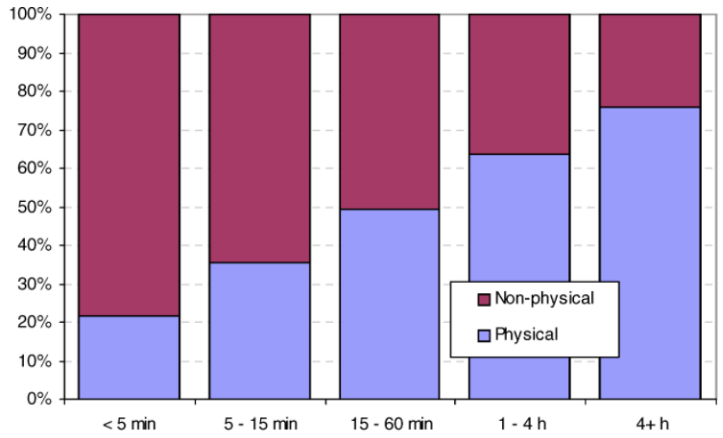
$$\lambda = \beta * I_t$$



Defining 'contacts'

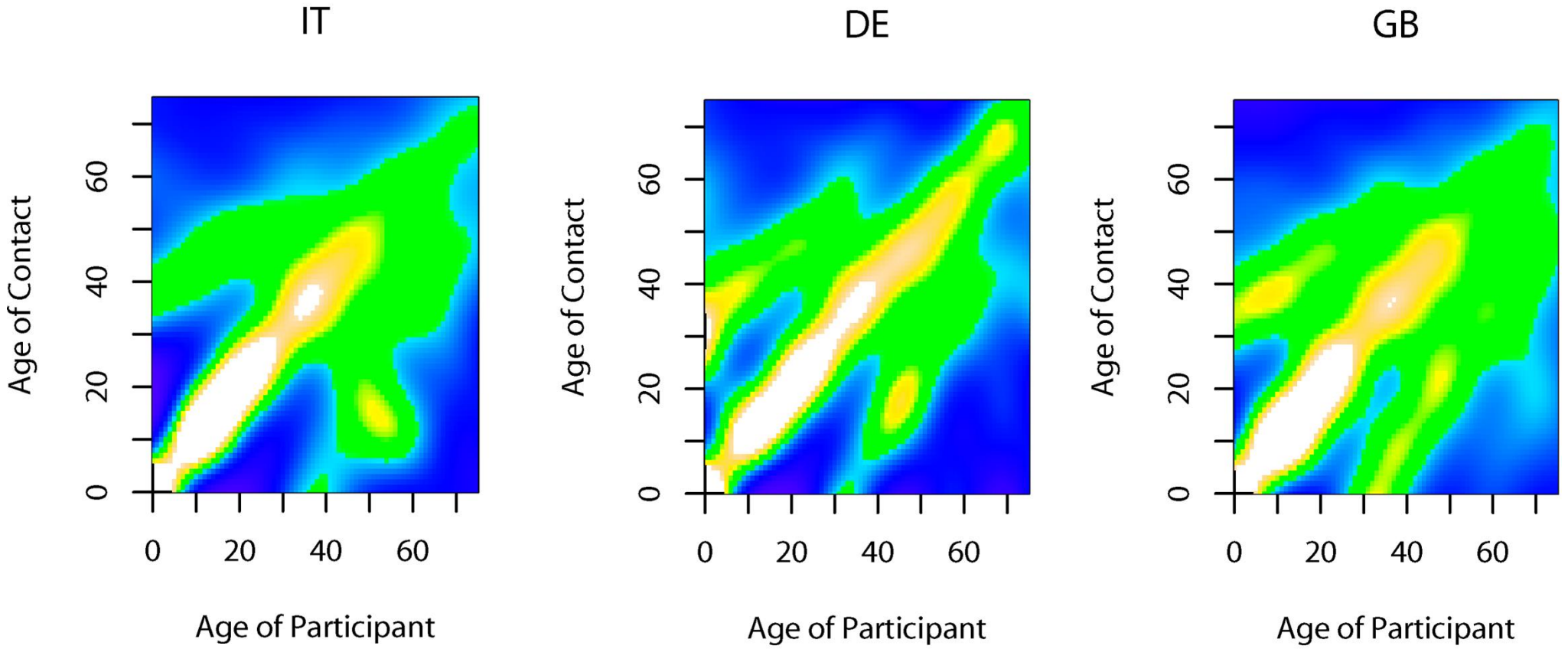
Definition of an (effective) contact

- Often difficult to know
  - How many contacts that could have led to respiratory / enteric disease transmission did you have yesterday?
- $\lambda = \beta * I_t$
  - β is **per-capita rate of effective contact** and can be estimated from a model (often is) but hard to measure empirically

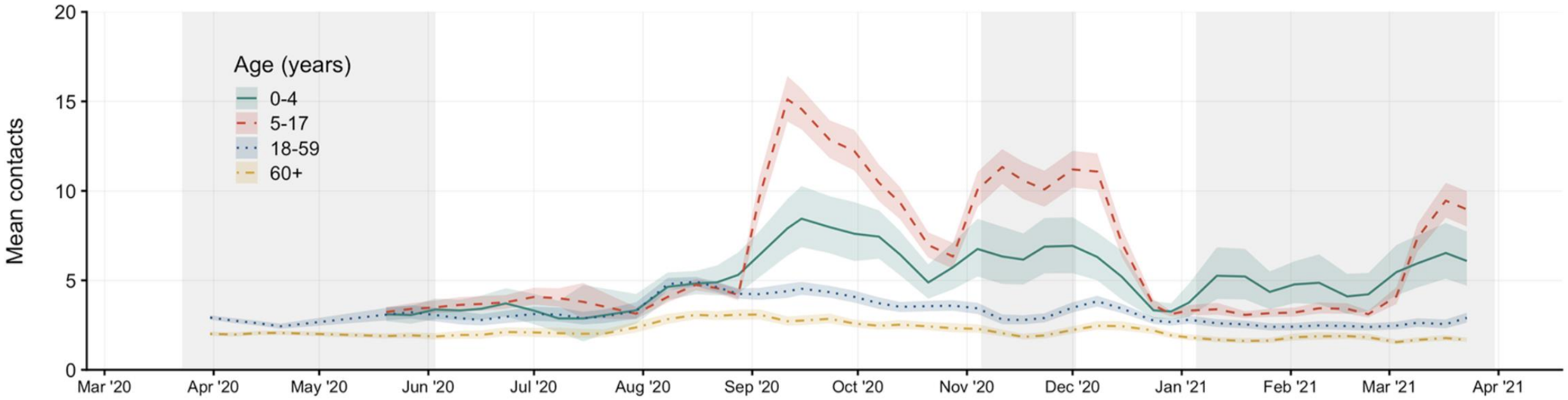


Mossong et al. 2008

Social contact patterns: who interacts with whom?

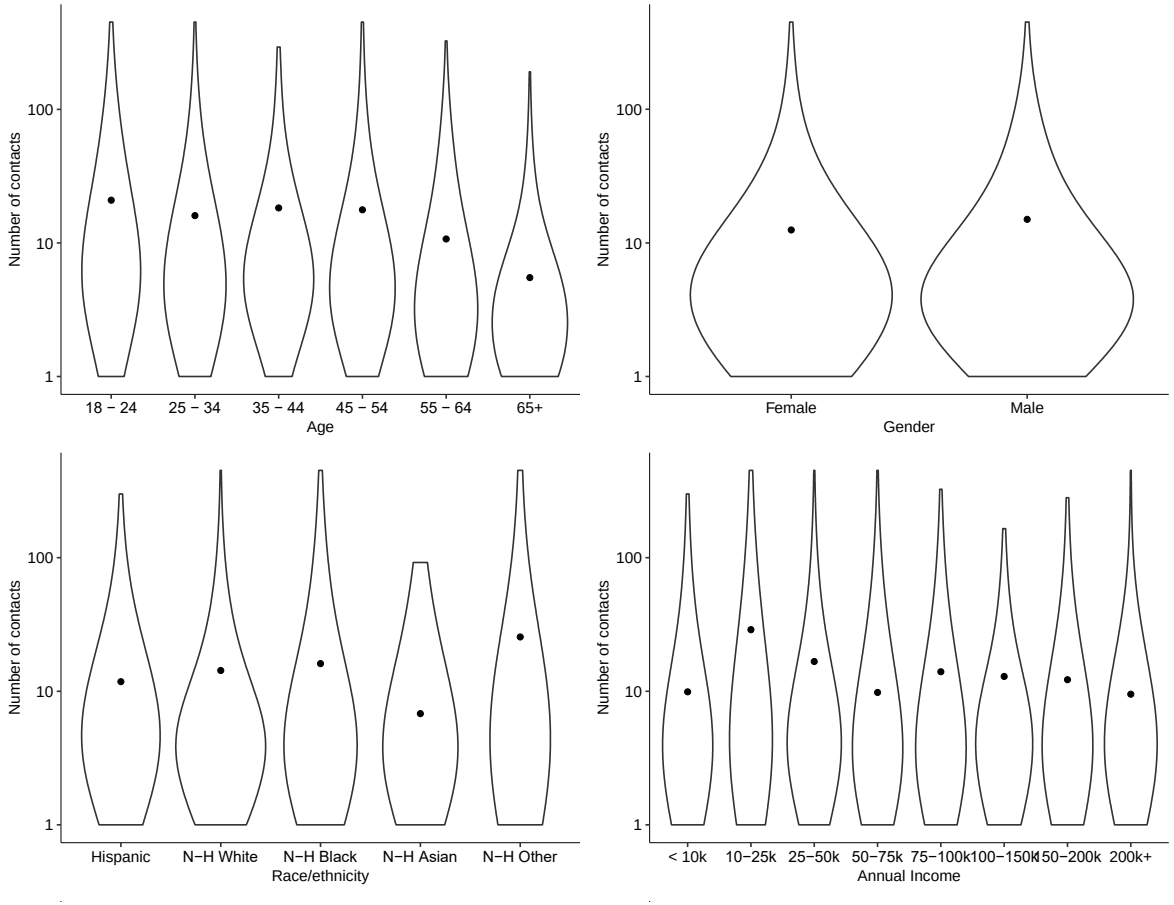


Social contact patterns change through time

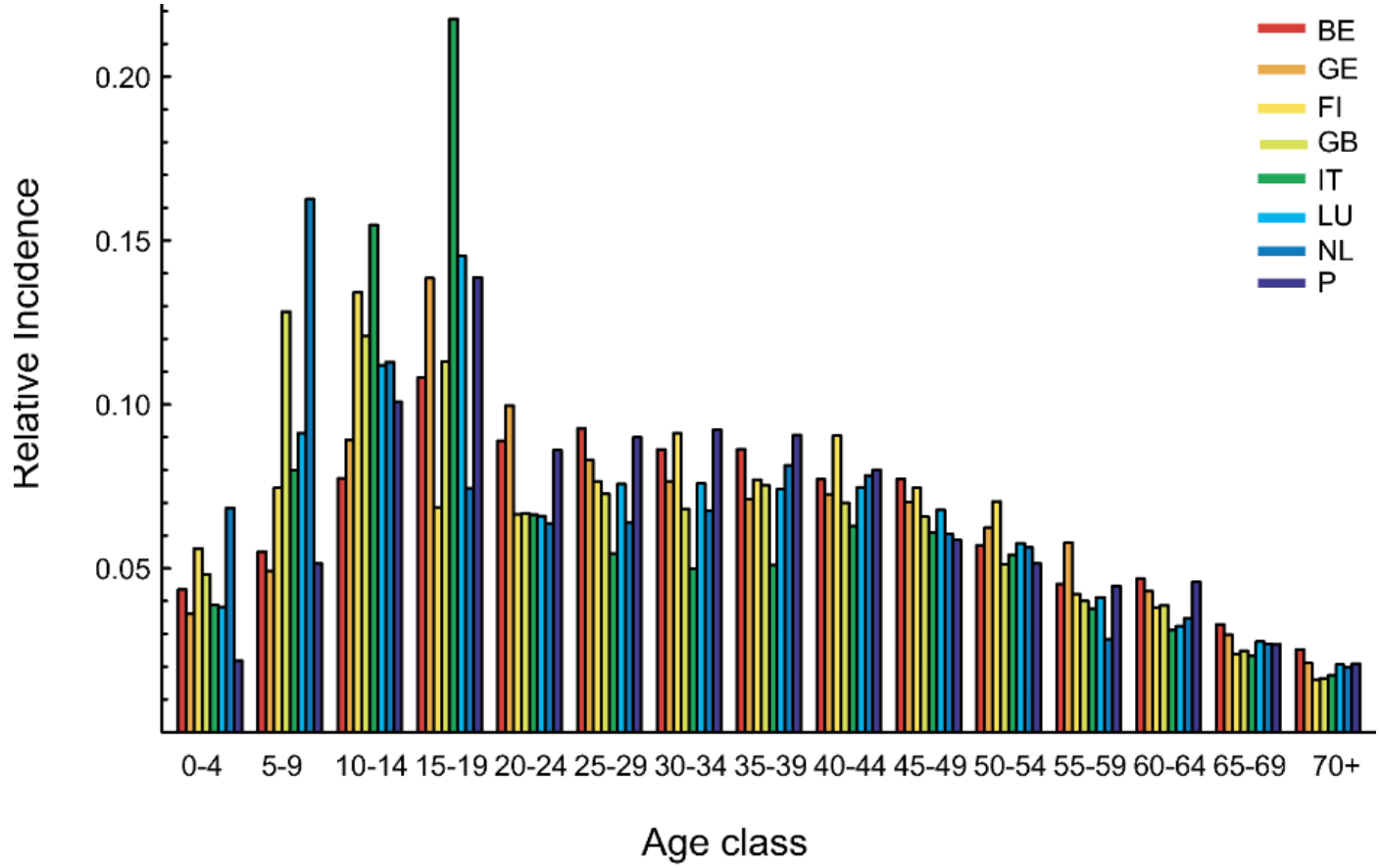


Gimma *et al*. PlosMed 2022

Social contacts rates differ within populations

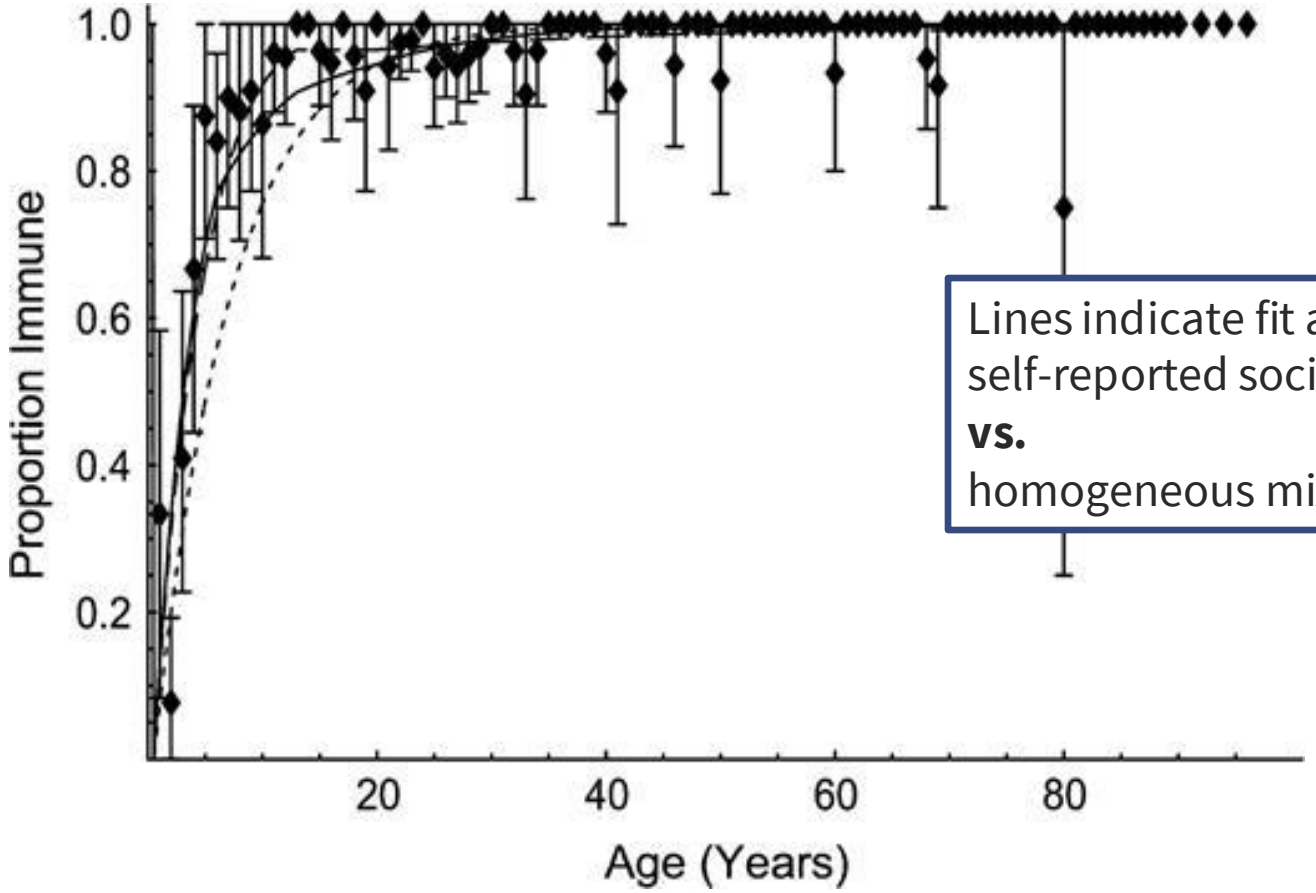


Model outputs depend on assumptions about social contact patterns



Mossong *et al*. PlosMed 2008

Social contact patterns, as measured in those studies, are linked with infection risk

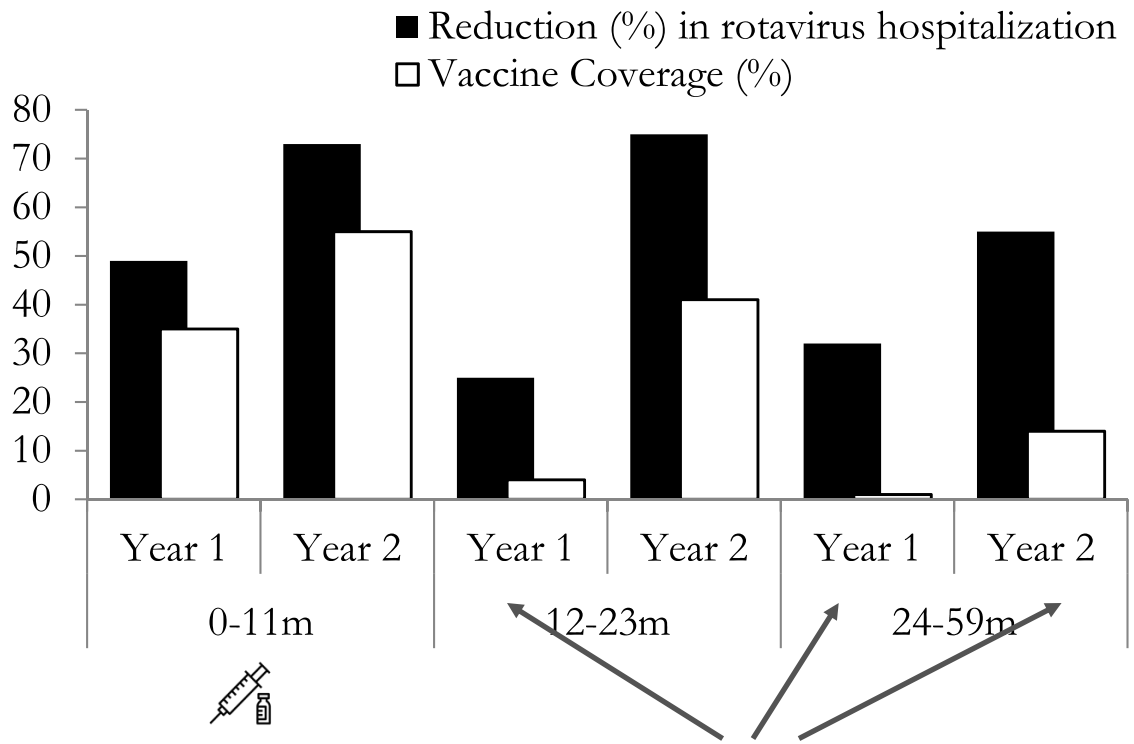


Lines indicate fit according to the hypotheses of:
self-reported social contacts (solid line)
vs.
homogeneous mixing (short-dashed line)

Wallinga et al. AJE 2006

Measuring transmission-reducing effects of vaccines

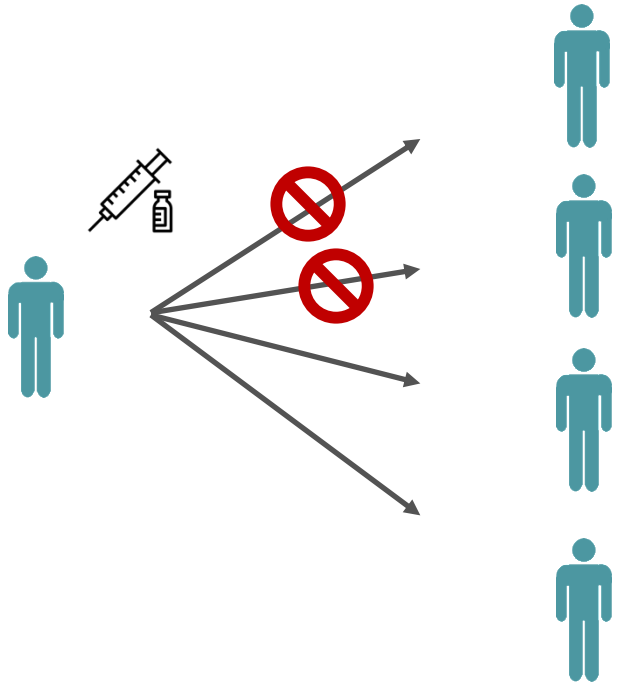
Rotavirus hospitalization data for two years post-rotavirus vaccine introduction in Moldova

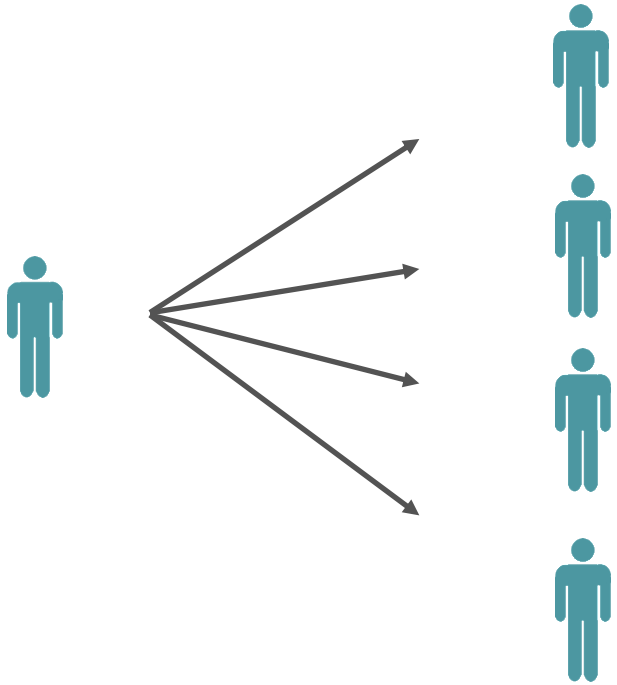


Too old to have received vaccine

Indirect (transmission-reducing) vaccine effects

Indirect (transmission-reducing) vaccine effects





Infected despite being vaccinated, but **less infectious**

Data from Europe has been used to project social contact patterns in many other countries

RESEARCH ARTICLE

Projecting social contact matrices in 152 countries using contact surveys and demographic data

Kiesha Prem[1], Alex R. Cook[1,2,3]*, Mark Jit[4,5]

1 Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore, Singapore, **2** Program in Health Services and Systems Research, Duke-NUS Graduate Medical School, Singapore, Singapore, **3** Department of Statistics and Applied Probability, National University of Singapore, Singapore, Singapore, **4** Department of Infectious Disease Epidemiology, London School of Hygiene & Tropical Medicine, London, United Kingdom, **5** Modelling and Economics Unit, Health Protection Agency Centre for Infections, London, United Kingdom

Countries

Polymod countries
Belgium
Germany
Finland
Italy
Luxembourg
Netherlands
Poland
United Kingdom

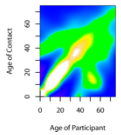
DHS countries
Bangladesh
Bolivia
Ghana
India
Indonesia
Philippines
Sierra Leone
Uganda
Zambia

Data Sources

No. of countries	Polymod 8	DHS 9	ROW 135
Data			
Individual-level contact data[a]	✓	×	×
Household-age structure[a] [e]	✓	✓	×
Population age composition[b]	✓	✓	✓
Labour force participation [c]	✓	✓	✓
Pupil-to-teacher ratio[d]	✓	✓	✓
School enrolment rates[d]	✓	✓	✓
Socio-demographic indicators[f]	✓	✓	✓

DHS: Demographic and Health Survey
ROW: Rest of the World

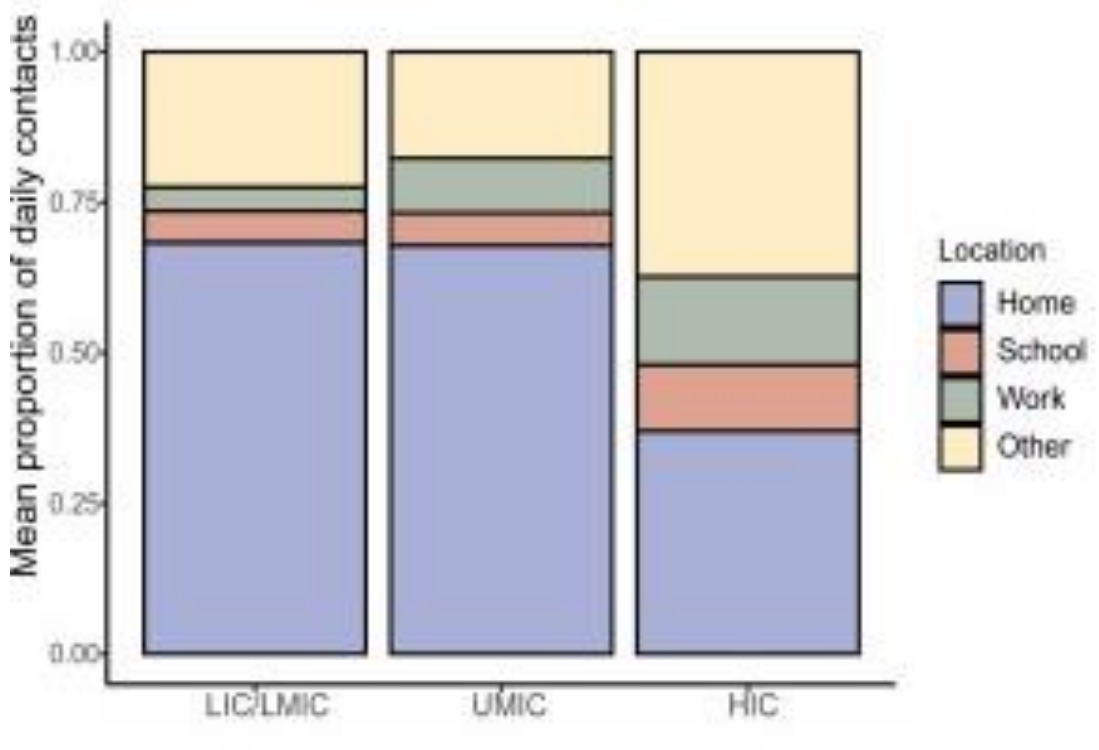
Data source
[a] Mossong et al. (2008)
[b] United Nations Statistics Division
[c] International Labour Organization
[d] United Nations Educational, Scientific and Cultural Organization Institute for Statistics
[e] Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys
[f] The World Bank

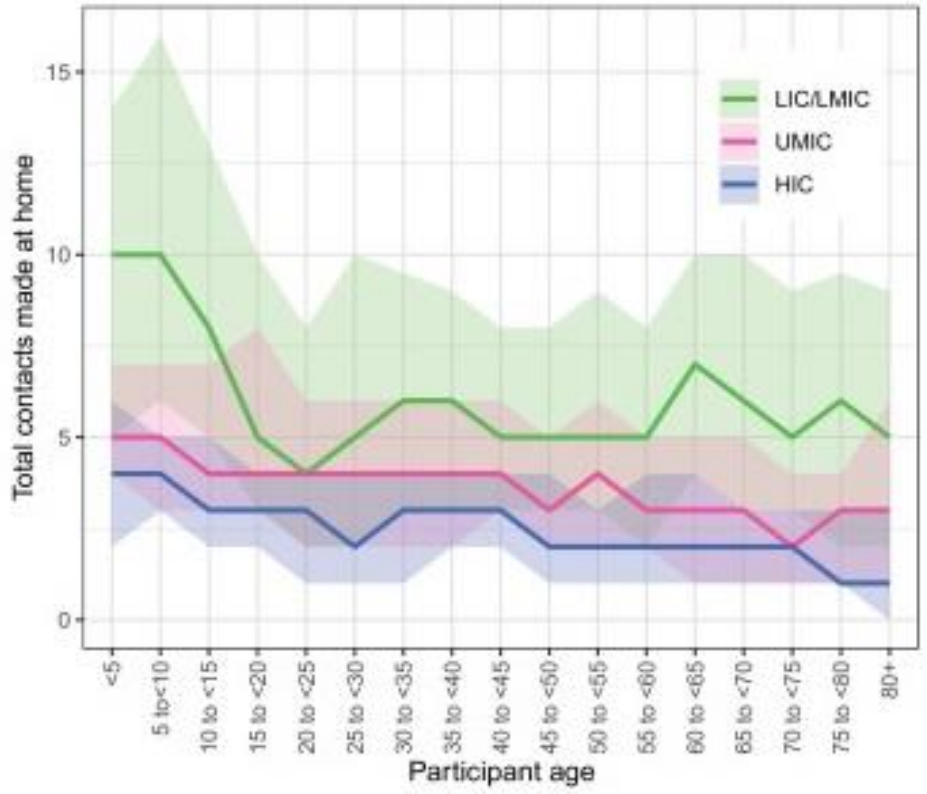


*POLYMOD + this paper cited **over 4k times** since published in 2008

PLOS | COMPUTATIONAL BIOLOGY

In low- and middle-income countries, more contacts at home and among older adults





Mousa *et al*, ELife 2021

The GlobalMix study

Objective: Characterize social mixing patterns across rural and urban settings in four countries: Guatemala, India, Mozambique, Pakistan

UVG UNIVERSIDAD DEL VALLE DE GUATEMALA

THE AGA KHAN UNIVERSITY

cism centro de investigação em saúde de manhiça

NOT TO BE MINISTERED UNTO BUT TO MINISTER
CHRISTIAN MEDICAL COLLEGE VELLORE INDIA

EMORY | ROLLINS SCHOOL OF PUBLIC HEALTH

Yale University
LUX ET VERITAS

The GlobalMix study design

Extensive qualitative work to inform data collection procedures

- Aguolu and Kiti *et al.* 2024

600 participants per site across age range

- 1200 per country

Two modes of data collection

- Individuals: 2-day contact diary
- Households: 5-day RFID sensors + contact diary

Oversample children (~25% under 5)

PLOS ONE

STUDY PROTOCOL

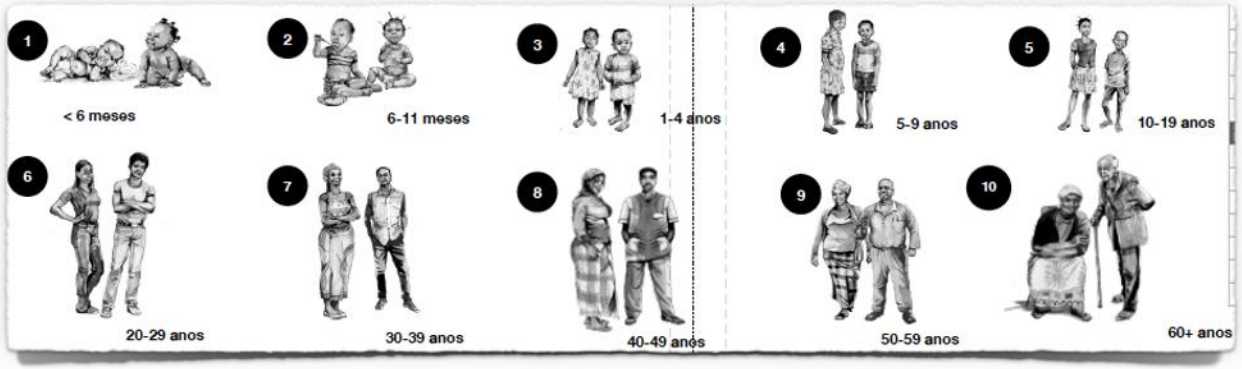
Comprehensive profiling of social mixing patterns in resource poor countries: A mixed methods research protocol

Obianuju Genevieve Aguolu[1]*, Moses Chapa Kiti[2], Kristin Nelson[2], Carol Y. Liu[2], Maria Sundaram[3], Sergio Gramacho[2], Samuel Jenness[2], Alessia Melegaro[4], Charfudin Sacoor[5], Azucena Bardaji[5,6,7], Ivalda Macicame[8], Americo Jose[8], Nilzio Cavele[8], Felizarda Amosse[5], Migdalia Uamba[8], Edgar Jamisse[5], Corssino Tchavana[5], Herberth Giovanni Maldonado Briones[9], Claudia Jarquín[9], María Ajsivinac[9], Lauren Pischel[10], Noureen Ahmed[11], Venkata Raghava Mohan[12], Rajan Srinivasan[12], Prasanna Samuel[12], Gifta John[12], Kye Ellington[2], Orvalho Augusto Joaquim[5], Alana Zelaya[2], Sara Kim[2], Holin Chen[2], Momin Kazi[13], Fauzia Malik[11], Inci Yildirim[10], Benjamin Lopman[2‡], Saad B. Omer[11‡]

1 Division of Epidemiology, College of Public Heath, The Ohio State University, Columbus, Ohio, United States of America, **2** Rollins School of Public Health, Emory University, Atlanta, Georgia, United States of America, **3** Center for Clinical Epidemiology and Population Health, Marshfield Clinic Research Institute,

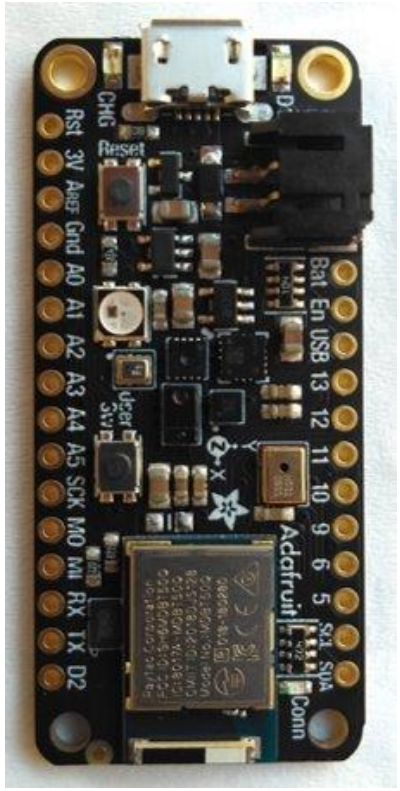
GlobalMix data collection tools

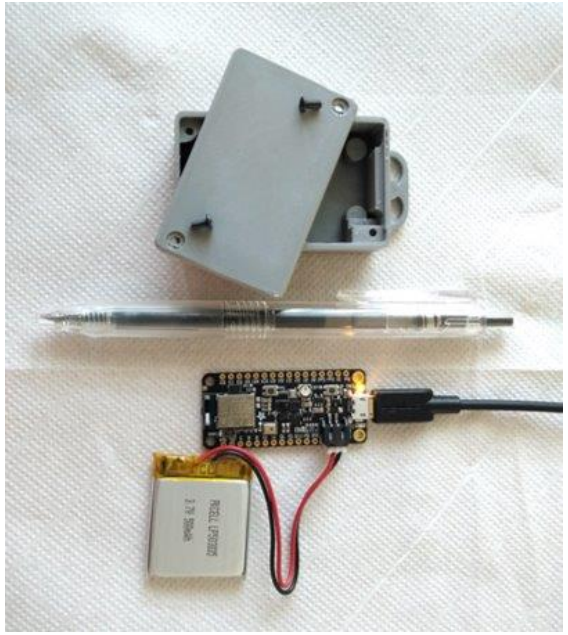
Nome	Idade (Escreva abaixo grupo de idade. Ex. Se uma criança, escreva "1")	Sexo	Relação	Tocaste a ele/ela?		O contact ocorreu dentro ou fora de edifício?		Logar de contacto. Escreva todos os locais onde você teve contato com essa pessoa.	A pessoa usava uma máscara?	Nos últimos 6 meses, com que frequência teve contacto com esta pessoa?	Há quanto tempo conhece esta pessoa?	Quanto tempo durou o contacto com esta pessoa?		Outros comentários
				Não	Sim	Dentro de edifício	Fora de edifício (ao ar livre)					hrs	min	



Slide courtesy of Moses Kiti, PhD

GlobalMix data collection tools





Photos courtesy of Moses Kiti, PhD

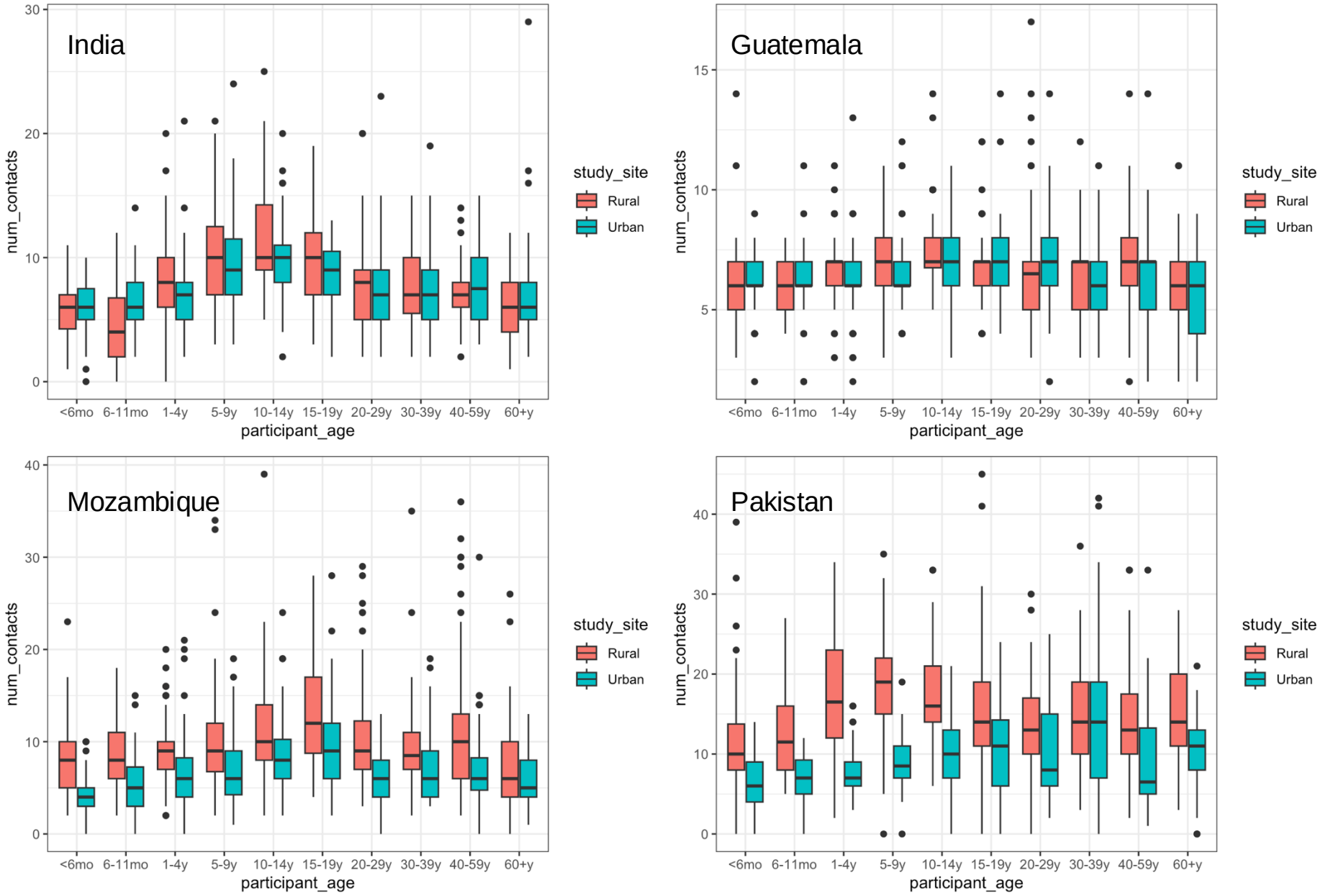
The GlobalMix study: results

	India				Guatemala				Mozambique				Pakistan			
	Urban		Rural		Urban		Rural		Urban		Rural		Urban		Rural	
N	622		622		566		575		687		676		627		607	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Age																
<6mo	55	8.8%	58	9.3%	52	9.2%	59	10.3%	66	9.6%	62	9.2%	86	13.7%	70	11.5%
6-11mo	55	8.8%	54	8.7%	58	10.2%	45	7.8%	64	9.3%	82	12.1%	40	6.4%	48	7.7%
1-4y	65	10.5%	61	9.8%	63	11.1%	55	9.6%	72	10.5%	63	9.3%	67	10.7%	68	10.8%
5-9y	63	10.1%	63	10.1%	52	9.2%	65	11.3%	58	8.4%	64	9.5%	42	6.7%	49	7.8%
10-14y	65	10.5%	64	10.3%	59	10.4%	56	9.7%	64	9.3%	61	9.0%	63	10.0%	59	9.4%
15-19y	67	10.8%	63	10.1%	43	7.6%	44	7.7%	60	8.7%	64	9.5%	64	10.2%	61	9.7%
20-29y	63	10.1%	62	10.0%	61	10.8%	64	11.1%	61	8.9%	64	9.5%	61	9.7%	55	8.8%
30-39y	63	10.1%	63	10.1%	47	8.3%	62	10.8%	61	8.9%	64	9.5%	70	11.2%	54	8.6%
40-59y	64	10.3%	71	11.4%	64	11.3%	61	10.6%	120	17.5%	89	13.2%	60	9.6%	79	12.6%
60+y	62	10.0%	63	10.1%	67	11.8%	64	11.1%	61	8.9%	63	9.3%	71	11.3%	61	9.7%
Missing													3		3	
Sex																
Female	326	52.4%	317	51.0%	363	64.1%	372	64.7%	334	48.6%	332	49.1%	267	42.6%	265	42.3%
Male	296	47.6%	305	49.0%	202	35.7%	203	35.3%	353	51.4%	343	50.7%	303	48.3%	299	47.7%
Missing	0	0.0%	0	0.0%	1	0.2%	0	0.0%	0	0.0%	1	0.1%	57	9.1%	43	6.9%
HH size	4.5				3.5				5.6				6.5			

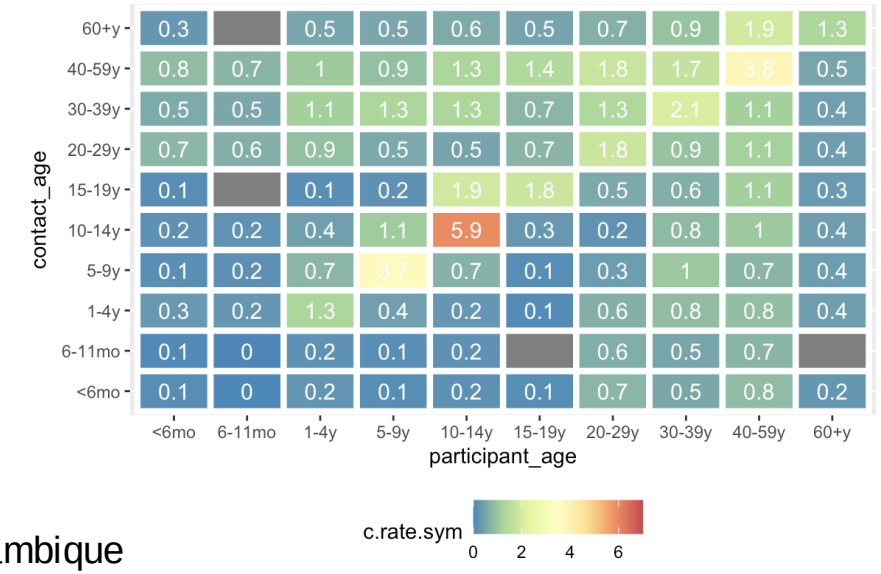
The GlobalMix study: results

Table 2. Characteristics of contacts reported by GlobalMix study participants by site

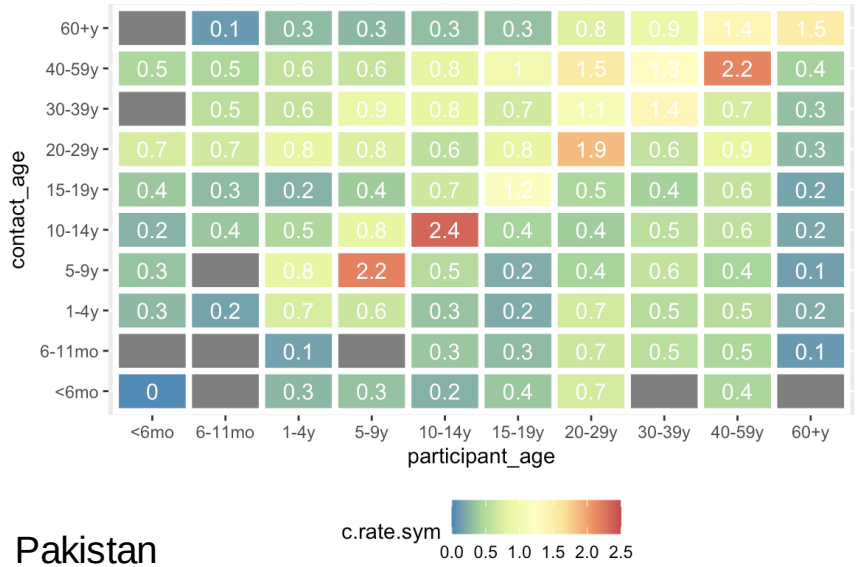
	India				Guatemala				Mozambique				Pakistan			
	Urban		Rural		Urban		Rural		Urban		Rural		Urban		Rural	
N	9745		9764		7153		7554		6988		10686		11108		18147	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Repeat contacts																
Repeat	4076	82.7%	3828	79.2%	2397	67.8%	2473	66.1%	1215	51.1%	1778	43.5%	4637	89.1%	7984	88.3%
Unique	851	17.3%	1004	20.8%	1124	31.8%	1240	33.2%	1161	48.9%	2307	56.5%	566	10.9%	1057	11.7%
Household member																
Yes	4312	44.2%	4462	45.7%	2908	40.7%	3066	40.6%	2306	33.0%	2406	22.5%	5048	45.4%	8192	45.1%
No	5433	55.8%	5302	54.3%	4245	59.3%	4488	59.4%	4682	67.0%	8279	77.5%	6060	54.6%	9955	54.9%
Physicality																
Touch	7089	72.7%	7095	72.7%	5061	70.8%	5123	67.8%	5062	72.4%	6620	62.0%	10809	97.3%	14140	77.9%
No touch	2241	23.0%	2302	23.6%	2020	28.2%	2360	31.2%	1915	27.4%	4054	37.9%	249	2.2%	2759	15.2%
Don't remember	225	2.3%	5	0.1%	2	0.0%	1	0.0%	10	0.1%	8	0.1%	50	0.5%	1248	6.9%
Location																
Indoors	5181	53.2%	5537	56.7%	5648	79.0%	6031	79.8%	837	12.0%	740	6.9%	6627	59.7%	2493	13.7%
Outdoors	1941	19.9%	2517	25.8%	1353	18.9%	1271	16.8%	2513	36.0%	5889	55.1%	2641	23.8%	2706	14.9%
Both	2433	25.0%	1348	13.8%	81	1.1%	183	2.4%	3637	52.0%	4055	37.9%	1805	16.2%	11718	64.6%
Missing	190	1.9%	362	3.7%	71	1.0%	69	0.9%	1	0.0%	2	0.0%	35	0.3%	1230	6.8%
Daily contacts	7.7		7.9		6.4		6.6		6.7		9.8		9.4		15.0	
	7.8 (5, 10)				6.5 (2, 7)				8.2 (5, 10)				12.2 (7, 16)			


India
Guatemala
Mozambique
Pakistan
num_contacts
participant_age
<6mo
6-11mo
1-4y
5-9y
10-14y
15-19y
20-29y
30-39y
40-59y
60+y
study_site
Rural
Urban

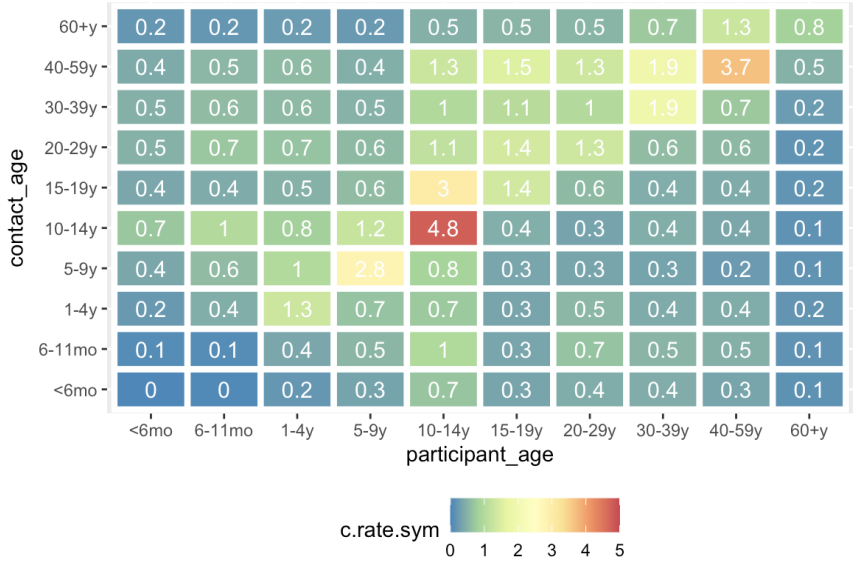
India



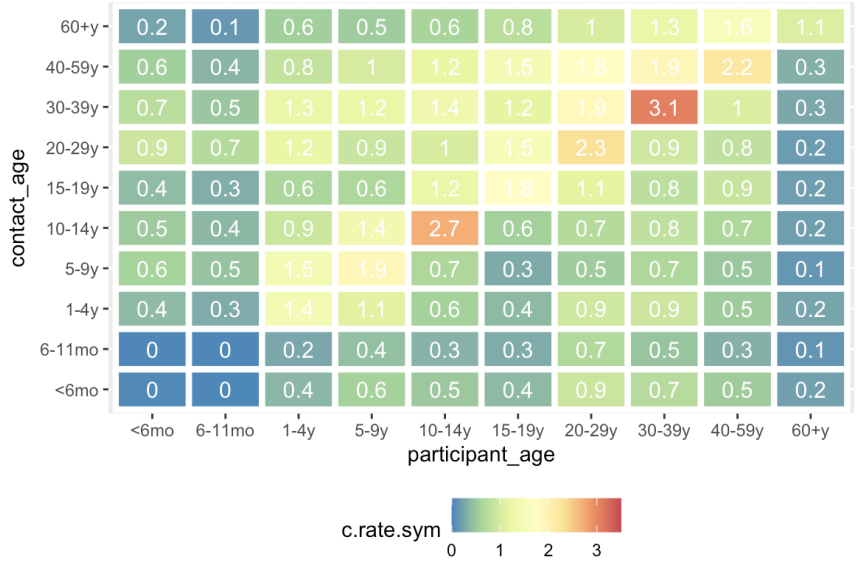
Guatemala



Mozambique

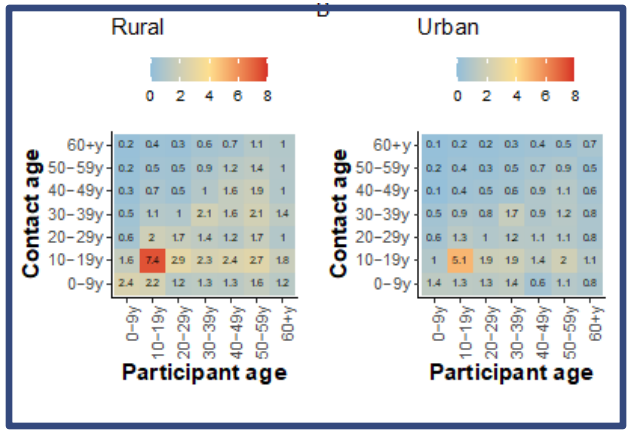


Pakistan

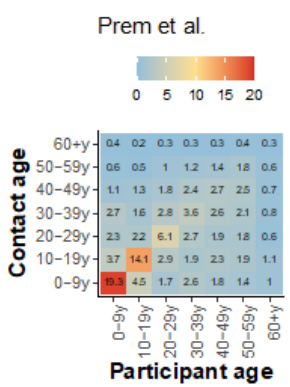


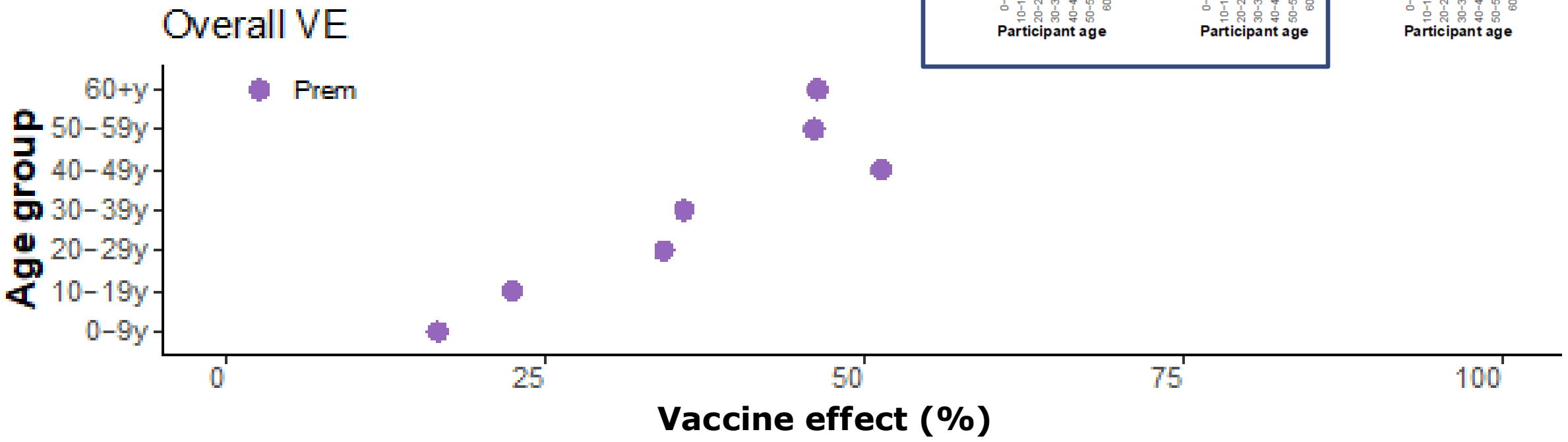
Assumptions about contact patterns affect conclusions about intervention effects

GlobalMix



POLYMOD proj

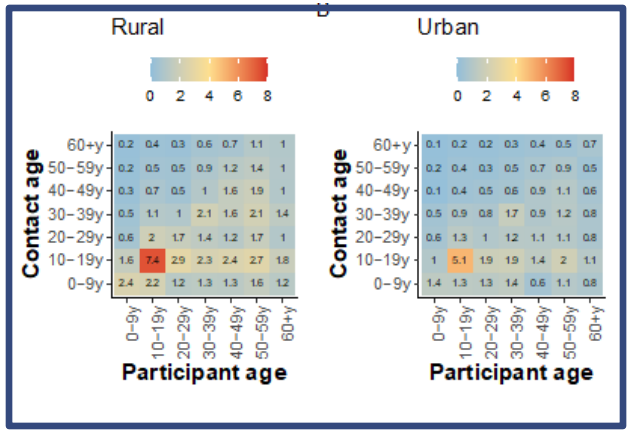




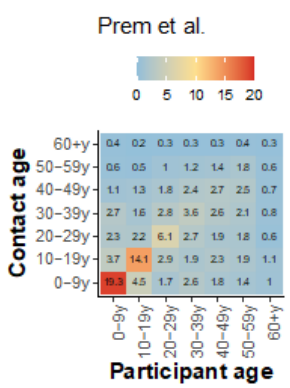
Kiti and Sacoor et al. EID 2025

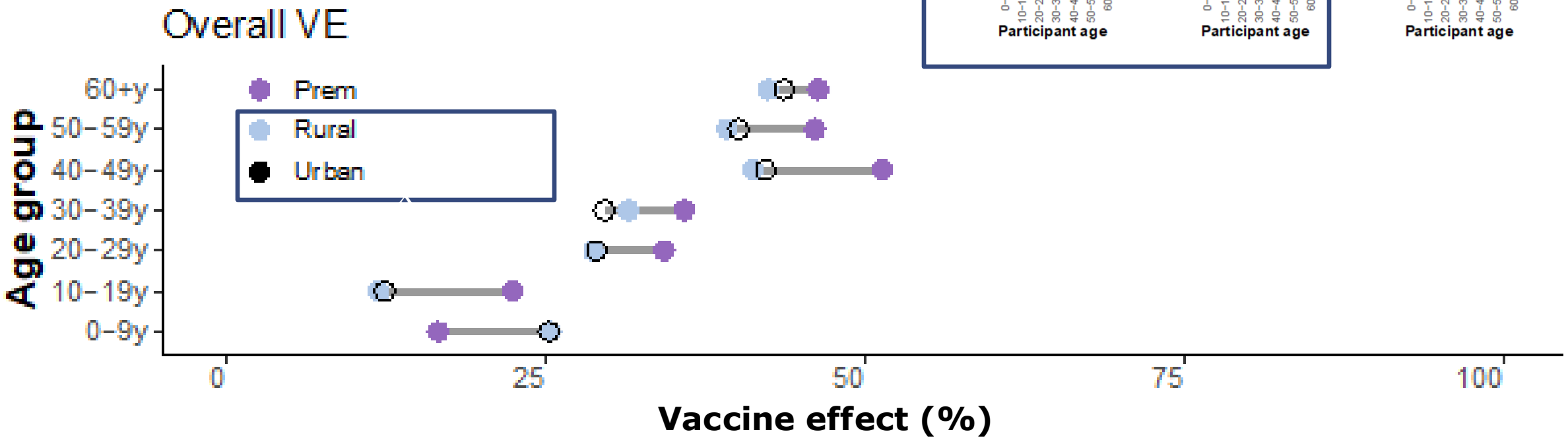
Assumptions about contact patterns affect conclusions about intervention effects

GlobalMix



POLYMOD proj





Kiti and Sacoor et al. EID 2025

India (and other) data is publicly available

https://github.com/lopmanlab/GlobalMix

Questions?