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A population's higher-risk sexual behaviour is associated with its average sexual behaviour—An ecological analysis of subpopulations in Ethiopia, Kenya, South Africa, Uganda and the United States

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ABSTRACT

Background: Given the large variation in the prevalence of sexually transmitted infections between populations it is important to characterize how sexual vary between populations. In this paper we assess how the distribution of lifetime sexual partners varies between populations. We ask: do populations with higher mean lifetime sexual partners merely differ by virtue of the presence of a core-group with increased number of partners or do the population distributions move as more coherent wholes?
Methods: We defined those in the top decile of lifetime sex partners in each country as constituting the higher-risk behaviour group (HRB). Spearman's correlation was used to evaluate the relationship between mean lifetime partners and prevalence of those in the HRB by ethnic group within Ethiopia, Kenya, South Africa, Uganda and the United States. In each case, data from nationally representative surveys were used. Two-sample Wilcoxon rank-sum were applied to test if there was a difference in the number of lifetime partners between the highest and lowest-risk subpopulations, separately for men and women. To account for autocorrelation, all analyses were conducted using means/medians excluding those in the HRB. A *P*-value of <0.05 was considered statistically significant.
Results: In each country, a positive correlation existed between subpopulations' mean lifetime partners and the prevalence of the HRB. Spearman's correlation varied from 0.20 to 0.99 for men and 0.74 to 1.0 for women. This association was statistically significant in 6 out of 10 comparisons. There was a statistically significant difference in the number of lifetime partners between the highest and lowest-risk ethnic groups in all countries except South Africa, where the difference was only significant for women.
Conclusions: Our results suggest that sexual behaviours vary coherently between different populations. As such, sexually transmitted infection control efforts would benefit from including both targeted campaigns focusing on the HRB and population-strategies that seek to address factors responsible for high mean risk behaviour.

1. Background

Given the dramatic variations in the prevalence of human immunodeficiency virus (HIV) and other sexually transmitted infections (STIs) in populations both between and within countries, it is important to understand how sexual behaviours vary between these populations (Kenyon et al., 2013a; Morris et al., 2009). This involves not just investigating variations in the average behaviour of populations and the prevalence of higher-risk behaviour, but also how these relate to one another.

Do trends in sexual behaviour of a population move as a coherent whole, or do sub-groups with higher-risk behaviour vary independent of the mean/rest of the population? A close association has been found between mean population blood pressure and the prevalence of hypertension (Rose and Day, 1990). Strong associations have also been found between populations' mean weight, cholesterol level, sodium and alcohol intake and the prevalence of those respectively classified as being overweight, hypercholesterolaemic, and consuming excessive sodium and alcohol (Rose, 1993a; Ouyang et al., 2015; Laaser et al., 2001; Chaiton et al., 2008; Razak et al., 2013). This association has been suggested to result from

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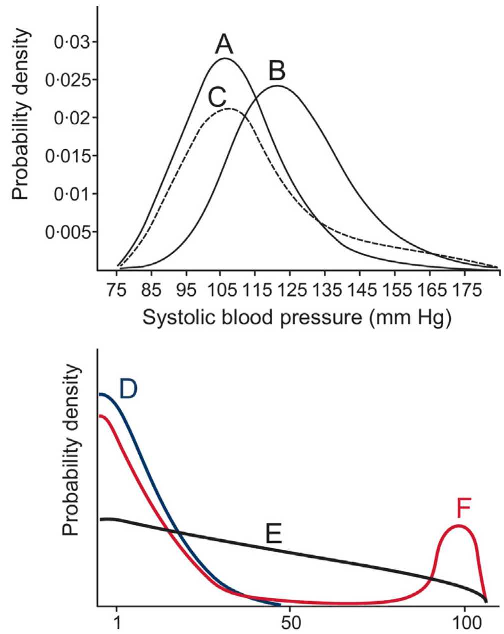

Fig. 1. Distributions of systolic blood pressure for the averages of the five populations with the lowest mean values (A) and the five with the highest values (B) from the Intersalt Study. A positive association between mean and prevalence of hypertension could be due to either a right shift in the entire population distribution curve (B) or due to a right skewing of the population distribution (C) where the left hand part of the population distribution remains unchanged [Based on figure from reference (Rose and Day, 1990)]. (ii) In the case of lifetime sex partners, where the left side of the distribution curve is relatively fixed, a positive association between mean and prevalence of those with 100 or more sex partners could either be due to a shift of the whole population distribution curve from (D) to (E), or a shift mainly in the proportion who have 100 or more partners (F). The change in the distribution from (D) to (E) can be visualized as a flattening of the distribution.

a conformity bias (peer pressure) which acts to promote conformity in norms and behaviours within populations (Rose and Day, 1990; Rose, 1993a; Cialdini and Goldstein, 2004; Christakis and Fowler, 2008). In turn, this constrains the amount of variation tolerated within populations (Rose, 1993b). Consequently, behaviour in populations tends to vary in a synchronized fashion and different populations may differ in both average and high-risk behaviour.

In this paper we assess if the same relationship between average behaviour and prevalence of high-risk behaviour applies to sexual behaviour. We investigate the relationship between the average number of lifetime sex partners and the prevalence of those with higher-risk behaviour by ethnic groups within five countries: Ethiopia, Kenya, South Africa, Uganda and the United States of America (USA). Higher-risk behaviour (HRB) is defined as being the top decile for reported lifetime sexual partners in that country. HIV prevalence varies by up to 50 fold by ethnic group within these countries (Table 1) and the reasons for this remain incompletely elucidated (Shisana et al., 2014). Number of lifetime partners has been established as an important risk factor for a large number of STIs including HIV at an individual level (Mishra et al., 2009; Central Statistical Agency [Ethiopia] and ICF International, 2012). At a population level some (Kenyon et al., 2013a, 2015) but not all (Auvert et al., 2001) studies have found a positive association between mean number of lifetime partners by ethnic group and HIV prevalence.

The distribution of the number of partners is an important variable in STI epidemiology in two ways. First, the shape of the distribution may inform what is determining the variation in mean values. Do ethnic groups with higher average lifetime partners simply have an increase in the size of the HRB (slope F in Fig. 1) or do they have a more generalized increase in the lifetime partners throughout the population (slope E)? If the higher average lifetime partners is determined by this latter right shift of the population distribution, then this suggests the size of the HRB is associated with and may be influenced by average behaviour (average number of life partners). This is also of considerable public health relevance: if the mean is driven up purely by an enlarged HRB, then strategies targeting the HRB are most appropriate. Alternatively, if there is evidence of a more general shift, then strategies targeting the general population should be prioritized.

Second, an important principle of STI epidemiology is that the magnitude of the variance of number of sex partners, in addition to the mean number of partners, plays a crucial role in determining the value of the basic reproductive number (May and Anderson, 1987; Cooke and Yorke, 1973; Hethcote and Yorke, 1984). Consequently, a small sexually active 'core-group' can be responsible for STI persistence in a larger population. Previous studies have argued that a power law exists between the variance and mean of the reported numbers of sex partners (Anderson, 1991; Anderson and May, 1988). Thus, a logarithmic plot of the relationship between the variance in the number of different sexual partners per unit of time versus the mean number of partners produces a straight line. Anderson and May (1988) first reported this association using data from a wide range of published and unpublished studies. These studies used different sampling methods, sampled a range of heterosexual and homosexual populations in the developed and developing world, and recorded number of partners from a period that ranged from the past month to the respondent's lifetime. The same result was found using data from a behavioural survey of men and women in England and Wales (Anderson, 1991). Once again, means and variances were calculated for samples stratified by age, sex and period of recall (1 month to lifetime). There is, however, considerable debate on this topic in the literature. For example, a subsequent study using more rigorous statistical techniques found that the best fitting models for the relationship between the variance and mean of the reported numbers of sex partners does not have a power-law tail (Jones and Handcock, 2003; Morris et al., 2008). In this paper we examine if an association exists between mean and variance of number of sex partners by ethnic group stratified by gender in five countries.

2. Methods

The five countries included in our analysis were selected based on the presence of each of the following criteria: (1) availability of nationally representative surveys that included a question on lifetime number of sex partners; (2) high heterogeneity in human immunodeficiency virus (HIV) prevalence between ethnic groups within these countries; and (3) evidence of homophily in choice of sexual partners within the ethnic groups being compared. The subpopulations compared were ethnic/racial group in all countries. In the USA, we also compared men who had sex with men and those who reported no sex with men. For Ethiopia, Kenya, and Uganda, we used region of residence as a proxy for ethnic/racial group, for the following reasons: many ethnic groups exist in each of these countries (over 80 in Ethiopia); ethnic group is highly correlated with region of residence; HIV prevalence varies considerably by region in each of these countries (Table 1); and the surveys used were designed to provide representative samples at the regional level but not for each ethnic group (Central Statistical Agency [Ethiopia] and ORC Macro, 2005; Kenya National Bureau of Statistics (KNBS) and ICF Macro, 2010; Uganda Ministry of Health, 2012).

We defined the HRB group as the decile of men or women in each country reporting the most lifetime sex partners. The threshold numbers of partners for entry into the HRB for women and men

Table 1
Age, HIV prevalence and sexual behaviour of survey participants in Ethiopia, Kenya, South Africa, United States and Uganda.

	N	Age (median)	% in poorest category[a]	HIV prevalence (%)[b]	Percent in higher-risk category[c,d]		Mean no. lifetime sex partners (standard deviation)/median (IQR)[e]	
					Men	Women	Men	Women
Ethiopia								
Tigray	1242	28	22.5	2.1	9.5	0.7	1.8 (0.16)/1 (0–2)	1.0 (0.06)/1 (1–2)
Affar	742	30	48.6	2.9	20.1	0.7	3.4 (0.34)/1 (0–3)	1.0 (0.06)/1 (1–1)
Amhara	1978	27	20.0	1.7	12.0	2.2	2.3 (0.16)/1 (0–2)	1.3 (0.05)/1 (1–2)
Oromiya	237	26	14.1	1.4	7.0	0.5	1.8 (0.14)/1 (0–2)	0.7 (0.03)/1 (1–1)
Somali	668	29	40.0	0.7	0.7	0.0	1.3 (0.36)/1 (0–1)	0.7 (0.04)1 (1–1)
Benishangul-Gumuz	867	27	25.9	0.5	11.0	0.8	2.2 (0.18)/1 (0–3)	1.2 (0.13)/1 (1–2)
SNNP	2197	27	19.4	0.2	6.5	0.0	1.6 (0.12)/1 (0–2)	0.7 (0.03)/1 (1–1)
Gambela	755	26	20.8	6.0	28.6	1.6	4.5 (0.58)/2 (1–5)	1.2 (0.08)/1 (1–2)
Harari	901	26	1.4	3.5	11.0	0.2	3.0 (0.42)/1 (1–3)	0.7 (0.04)/1 (1–1)
Addis Ababa	1983	25	0.2	4.7	16.8	0.6	3.5 (0.34)/1 (0–3)	0.8 (0.20)/1 (1–2)
Dire Dawa	833	27	5.1	3.2	8.4	0.8	2.1 (0.29)/1 (0–2)	0.8 (0.09)/1(1–2)
Spearman's rho (*P*-value)[c,d]			M: 0.03 (0.925)[a] W: 0.14 (0.687)	M: 0.71 (0.015)*,[b] W: 0.48 (0.137)	Incl: 0.97 (0.000)***,[d] Excl: 0.99 (0.000)***	Incl: 0.91 (0.000)***,[d] Excl: 0.81 (0.003)**	0.56 (0.071)[e]	0.61 (0.046)*,[e]
Kenya								
Nairobi	1375	28	0	7.0	9.5	6.0	5.3 (0.47)/4 (1–6)	1.9 (0.08)/1 (0–2)
Central	1361	29	2.1	4.6	22.4	6.5	7.3 (0.66)/3 (1–7)	2.1 (0.15)/2 (1–3)
Coast	1589	28	20.7	4.2	22.2	2.5	7.5 (0.62)/3 (1–8)	1.6 (0.06)/1 (1–2)
Eastern	1576	28	15.2	3.5	11.3	4.1	3.9 (0.39)/2 (0–4)	1.7 (0.06)/1 (1–2)
Nyanza	1855	26	15.2	13.9	14.1	4.8	4.5 (0.31)/3 (1–5)	2.0 (0.04)/2 (1–3)
Rift valley	1815	27	21.9	4.7	13.7	2.5	5.1 (0.47)/2 (1–5)	1.4 (0.04)/1 (1–2)
Western	1488	26	15.6	6.6	19.3	4.7	7.1 (0.68)/2 (1–5)	1.9 (0.10)2 (1–2)
North-Eastern	824	26	69.6	0.9	1.8	0.0	1.2 (0.13)/1 (0–1)	0.8 (0.02)/1 (1–1)
Spearman's rho (*P*-value)[c,d]			M: −0.21 (0.610) W: −0.95 (0.000)***	M: 0.19 (0.615) W: 0.59 (0.119)	Incl: 0.81 (0.012)* Excl: 0.36 (0.385)	Incl: 0.98 (0.0001)*** Excl: 0.74 (0.036)*	0.86 (0.006)*	0.71 (0.047)*
South Africa								
Black	8225	28	36.7	15.0	20.6	20.3	6.7 (0.29)/4 (1–8)	3.3 (0.14)/2 (1–4)
Coloured	1447	32	5.2	3.1	10.6	7.2	4.9 (0.50)/3 (1–5)	1.9 (0.23)/1 (1–2)
White	183	40	0.8	0.3	3.2	8.5	3.7 (0.67)/3 (1–5)	2.1 (0.30)/2 (1–3)
Indian	171	31	1.6	0.8	3.6	6.8	3.0 (0.31)/2 (0–5)	1.6 (0.52)/1 (0–1)
Spearman's rho (*P*-value)[c,d]			M: 1.0 (0.000)*** W: 0.40 (0.600)	M: 1.0 (0.000)*** W: 0.40 (0.600)	Incl: 0.80 (0.200) Excl: 0.20 (0.800)	Incl: 1.0 (0.000)*** Excl: 1.0 (0.000)***	−0.40 (0.600)	−0.80 (0.200)
Uganda								
Central 1	1944	29	4.4	10.6	21.9	12.1	8.5 (0.60)/4 (2–7)	2.6 (0.12)/2 (1–3)
Central 2	2036	29	9.0	9.0	15.3	8.9	6.5 (0.53)/4 (2–7)	2.5 (0.16)/2 (1–3)
Kampala	2117	26	0.0	7.1	16.0	11.1	6.3 (0.56)/3 (1–6)	2.5 (0.08)/2 (1–3)
East Central	2252	29	13.7	5.8	18.2	9.0	7.2 (0.53)/4 (2–7)	2.5 (0.05)/2 (1–3)
Mid Eastern	2313	29	20.2	4.1	16.2	11.4	7.2 (0.58)/3 (1–6)	2.8 (0.20)/2 (1–3)
North East	1899	30	42.9	5.3	11.9	3.8	5.2 (0.56)/3 (1–5)	1.8 (0.10)/1 (1–2)
West Nile	2247	30	35.8	4.9	15.6	4.1	5.8 (0.54)/3 (2–5)	1.7 (0.10)/1 (1–2)
Mid Northern	2145	29	42.1	8.3	11.0	2.8	4.6 (0.31)/3 (1–5)	1.6 (0.07)/1 (1–2)
South Western	2017	30	5.3	8.0	10.6	1.9	4.6 (0.34)/2 (1–4)	1.5 (0.14)/1 (1–2)
Mid Western	2246	28	11.6	8.2	15.1	6.1	6.6 (0.72)/3 (1–6)	2.1 (0.08)/2 (1–3)
Spearman's rho (*P*-value)[c,d]			M: −0.32 (0.366) W: −0.46 (0.187)	M: −0.09 (0.802) W: 0.03 (0.934)	Incl: 0.89 (0.000)*** Excl: 0.61 (0.060)	Incl: 0.94 (0.000)*** Excl: 0.90 (0.0003)**	0.58 (0.081)	0.36 (0.310)
USA by ethnicity								
Mexican American	2029	40	36.1	0.5	10.7	4.8	12.1 (0.69)/5 (2–12)	4.0 (0.26)/2 (1–4)
Other Hispanic	1377	45	36.3	0.4	13.5	6.1	16.1 (0.83)/10 (4–20)	4.9 (0.39)/3 (1–5)
Non-Hispanic White	5467	48	18.6	0.2	14.3	13.5	14.9 (0.70)/8 (3–20)	7.8 (0.42)/5 (2–10)
Non-Hispanic Black	3007	46	38.5	1.6	25.3	12.2	23.4 (0.78)/12.5 (6–30)	8.5 (0.43)/5 (3–9)
Other Race	1494	39	22.9	0.0	8.2	9.3	9.9 (1.37)/3 (1–9.5)	5.7 (0.97)/2 (1–5)
Spearman's rho (*P*-value)[c,d]			M: 0.40 (0.506) W: −0.30 (0.624)	M: 0.60 (0.284) W: −0.20 (0.747)	Incl: 0.90 (0.037)* Excl: 0.90 (0.037)*	Incl: 0.90 (0.037)* Excl: 0.80 (0.104)	0.80 (0.200)	1.0 (0.000)***

Table 1 (*Continued*)

	N	Age (median)	% in poorest category[a]	HIV prevalence (%)[b]	Percent in higher-risk category[c,d]		Mean no. lifetime sex partners (standard deviation)/median (IQR)[e]	
					Men	Women	Men	Women
USA by orientation								
MSM	209	44	26.9	7.2	25.3	NA	26.9 (7.8)/8 (3–20)	NA
MSW	4149	42	21.5	0.2	14.0	NA	14.8 (1.6)/22 (4–100)	NA

P-value * <0.05, ** <0.005, *** <0.0005.

[a] 'Percent in the poorest category' refers to the percent of respondents that were found in the survey to be in the poorest wealth quintile (Ethiopia, Kenya, Uganda) or the poorest tertile (South Africa, USA). Spearman's correlations refer to correlation between percent in poorest category and percent in high-risk group for men (M) and women (W).

[b] HIV prevalence obtained from each of the same surveys that provided the sexual behaviour data except South African where HIV testing was not done as part of the NCS survey, For South Africa, HIV prevalence is taken from a seroprevalence survey that obtained representative samples from each racial group in 2012 (Shisana et al., 2014). Spearman's correlations in 'HIV Prevalence' (4th) column refer to Spearman's correlation between percent in higher-risk category and HIV prevalence for men (M) and women (W).

[c] Percent in the higher-risk group defined as those reporting more than a threshold of lifetime sexual partners (3/5 in Ethiopia, 5/10 in Kenya, South Africa and Uganda and 15/30 in the United States for men/women).

[d] Figures in '% in higher-risk category' (5th) column refer to Spearman's correlation between percent in higher-risk category and mean number of lifetime sex partners per ethnic group using means that include (Incl) and exclude (Excl) the individuals in the higher-risk category.

[e] The Mean and Median no. Lifetime Sex Partners are the means and medians calculated for the entire population—including the HRB. The Spearman's correlation figures in these (7th and 8th) columns refer to correlation between mean number of lifetime partners and variance in number of lifetime partners by ethnic group stratified by gender. IQR—interquartile range.

were 3 and 5 in Ethiopia, 5 and 10 in Kenya, South Africa and Uganda and 15 and 30 in the United States, respectively.

In each survey, respondents who answered that they had never had sex were given a value of zero life partners. Those who did not answer this question were excluded from the analyses. The lifetime number of partners was truncated at 100 to avoid outliers exerting a disproportionate impact. Because of differences in age composition between ethnic groups in South Africa and the USA, all rates for these countries were age-standardized using the direct method and the age structures derived from these countries' respective national census data.

2.1. Data

Ethiopia: The 2005 Ethiopia Demographic and Health Survey involved a two-stage stratified design that sampled 14,070 women aged 15 to 49 and the 6033 men aged 15 to 59 from all 11 regions of Ethiopia. The samples were representative for each of these regions (Central Statistical Agency [Ethiopia] and ORC Macro, 2005).

Kenya: The 2008 Kenyan Demographic and Health Survey utilized a household-based, two-stage stratified sampling approach, which provided representative estimates for each of the country's eight regions. A total of 12,677 persons were included. In each selected house, all women aged 15 to 49 who slept in that house the previous night were selected. In addition, in every second house all men aged 15 to 54 were selected to complete the survey (Kenya National Bureau of Statistics (KNBS) and ICF Macro, 2010).

South Africa: The 2012 National Communication Survey (NCS) was a cross-sectional survey that utilized a three-stage, stratified sampling approach. The survey produced a nationally representative sample of 10,034 individuals aged 16 to 55. The sampling strategy was not designed to provide samples that were representative for each racial group (Johnson et al., 2013).

Uganda: The 2011 Uganda AIDS Indicator Survey used a two-stage design to provide a sample of 21,742 persons aged 15 to 59 years that was representative for the country and for each of its 10 regions. All women and men aged 15 to 59 years who were usual residents or who slept in the selected households the night before the survey were eligible for inclusion (Uganda Ministry of Health, 2012).

USA: The National Health and Nutrition Examination Survey (NHANES) 2009–2012 survey obtained stratified, multistage probability samples of the civilian, non-institutionalized population. Mexican Americans and Non-Hispanic Blacks were oversampled to ensure representative samples of these groups. All males and females aged 18 to 69 years who completed the sexual behaviour questionnaire were included. This was conducted via audio, computer-assisted self-interview (ACASI) in a mobile examination center. Race and ethnicity were self-selected by participants. Men who reported ever having had sex with another man were classified as men who have sex with men (MSM). Men who reported no sex with other men were classified as men who have sex with women (MSW) (Centers for Disease Control and Prevention, 2015).

Availability of supporting data: The DHS data sets are available from http://www.measureDHS.com and the NHANES data from http://www.cdc.gov/nchs/nhanes.htm.

Ethics approval: This research involved secondary data analysis of five surveys that each received ethical committee approval for data analyses such as the one performed here. All data is aggregated to the level of communities, preserving anonymity. No additional ethics committee approval was sought for this study.

2.2. Statistical analysis

A visual evaluation of the distribution of lifetime sex partners per subpopulation was initially done with the use of normalized histograms. In each country we classified the ethnic groups with the highest/lowest proportion of members in the HRB as the 'highest'/'lowest' risk groups. The results were the same whether men or women were used to determine this classification. We used the two-sample Wilcoxon rank-sum to test if there was a difference in the median number of lifetime partners between the highest and lowest-risk ethnic groups separately for men and women in each country.

Correlations between the mean and prevalence of higher-risk behaviour were examined visually by scatter plots and formally by calculating Spearman correlation coefficients. A positive association between mean and HRB could be due to either a right shift in the entire population distribution curve (from curve A to B or D to E in Fig. 1) or due to a right skewing of the distribution (C or F) where the left part of the population distribution remains relatively unchanged. The right skewing scenario would involve a form of autocorrelation where the high values would increase the overall mean, despite being independent from the characteristics of the main population (Rose and Day, 1990). To account for autocorrelation, we conducted the analyses twice—first excluding than including those in the HRB. We also repeated the Wilcoxon rank-sum analyses excluding individuals in the HRB. Spearman's correlation coefficient was also used to test the correlation between HIV prevalence and the proportion of the population in the HRB as well as the association between mean and variance in the number of lifetime sexual partners by ethnic group stratified by gender. In the case of the USA, we excluded the 'Other race' category from the analysis, as this composite-group had a large variance that exerted a large outlier effect on the association between mean and variance (Table 1).

In addition, we report the percent of respondents in each ethnic group in the lowest income category. In the three Demographic and Health Survey datasets (Ethiopia, Kenya, Uganda) we report the percent of households in the region that were in the poorest wealth quintile. The DHS divided households into wealth quintile based on reported household assets and services reported during the survey (Rutstein et al., 2004). In South Africa, households were divided into wealth tertiles based on a similar methodology (Johnson et al., 2013). In the USA, respondents reported household income and we divided the respondents into tertile income categories based on reported annual household income (Centers for Disease Control and Prevention, 2015). In South Africa and the USA, we report the percent that were in the lowest tertile category.

A *P*-value of less than 0.05 was considered statistically significant. Analyses were performed with STATA version 13 (STATA Corp., Texas, USA), using survey methodology to adjust for the survey characteristics.

3. Results

The characteristics of the survey participants by ethnic group, including their mean number of lifetime partners and the correlation between ethnic groups' mean lifetime partners and the prevalence of the HRB, are listed in Table 1. In each country the prevalence of the HRB was positively associated with mean lifetime partners (calculated excluding those in the HRB). Spearman's correlation varied from 0.20 to 0.99 for men and 0.74 to 1.0 for women; Table 1. The close to linear association between these two variables is depicted via scatterplots in Fig. 2. In the case of men in Kenya, South Africa and Uganda and women in South Africa, this association was not statistically significant. The associations were stronger and statistically significant for all comparisons (except for South African men) when mean lifetime partners was calculated including those in the HRB.

Visual comparison of the normalized histograms of the high and lowest-risk ethnic groups in each country demonstrated that it was not just the proportion in the HRB population that varied between these populations (Fig. 3). Rather, the lowest risk group had a higher proportion reporting low numbers of partners and a lower proportion reporting 4–6, 7–9 and 10 or more partners. As a result, the histograms of the lowest-risk groups exhibited steeper downsloping curves compared to the highest-risk groups, which had flatter trajectories. There was evidence of data heaping on multiples of 5, particularly in the USA data.

Statistically significant differences in the number of lifetime partners between the highest and lowest-risk ethnic groups were observed for all groups except Ethiopian and South African women (Table 2). The differences were statistically significant in all the repeated analyses that included the individuals in the HRB, except for South African women.

The association between the mean and variance in lifetime sexual partners by ethnic group stratified by gender was positive in all comparisons excluding those from South Africa (Table 1). The association was statistically significant in the case of the Kenyan women and men and the Ethiopian and USA women.

In general, the association between percent in the HRB and HIV prevalence was positive but this association was only significant in two comparisons (Ethiopian and South African men). There was no clear association between the percent in the HRB and percent in the poorest category: in one case each, the association was statistically significantly positive (South African men, $P < 0.001$) and negative (Kenyan women, $P < 0.001$).

4. Discussion

Our analysis suggests that a positive correlation exists between the mean number of lifetime sex partners and the prevalence of the HRB, with statistical significance demonstrated in 6 out of 10 comparisons. When the analyses were repeated using means including those in the HRB, the association was significant for all groups except South African men. There was a statistically significant difference in the median number of lifetime partners between the highest and lowest-risk ethnic groups in all countries excluding South Africa. The same was true for the comparison of MSM with MSW. These analyses suggest that the prevalence of those in the HRB is not independent of the mean. This finding in turn supports the interpretation that the behaviour of the overall population is coherent and that a population's average number of lifetime partners is associated with the prevalence of those in the HRB.

Although more research is required to understand the basis of this relationship, important clues may come from recent work that suggested that social networks play an important role in the spread of sexual norms and behaviours (Christakis and Fowler, 2008; Brakefield et al., 2014). Social networks may thus constitute a key pathway through which the conformity bias (commonly known as peer pressure) operates to constrain the amount of variation within populations (Cialdini and Goldstein, 2004).

The differences between the lowest and highest-risk ethnic groups' histograms are, however, far from the simple right shift of the bell curve that has been found when comparing the blood pressures of different populations (illustrated as curves A and B in Fig. 1) (Rose and Day, 1990). The number of sex partners may be more akin to body mass index (BMI) than blood pressure, in that the left side of the distribution curves of both BMI and sex partners are relatively fixed. A number of longitudinal studies have found that in populations with increasing average BMIs, most of this increase is due to increases at the upper part of the distribution curve and there is comparatively little movement in the left tail (Penman and Johnson, 2006; Block et al., 2013). There are however a number of caveats in comparing distribution curves of sex partners, BMI and blood pressure. These include the fact that BMI and blood pressure are continuous variables whereas number of sex partners is a discrete variable. None-the-less, the number of lifetime partners may be considered to be 'left-anchored' as is the case with BMI—even in higher-risk populations, a significant proportion of persons will likely still report zero, one or two partners. Rather than right shifting of a bell curve, it appears that the change in the distribution of lifetime number of partners from low to higher-risk populations would be more accurately described in terms of a flattening of the distribution. In low-risk populations the distribution is concentrated in the lower numbers of partners creating a steep down slope (curve D, Fig. 1), whereas in higher-risk populations the distribution is flatter (curve E). This variation in distribution of number of partners is not too different to that observed when comparing implicit and explicit norms (including those pertaining to sexuality) between populations (Greenwald and Farnham, 2000; Schmitt, 2005; Christensen and Gregg, 1970;

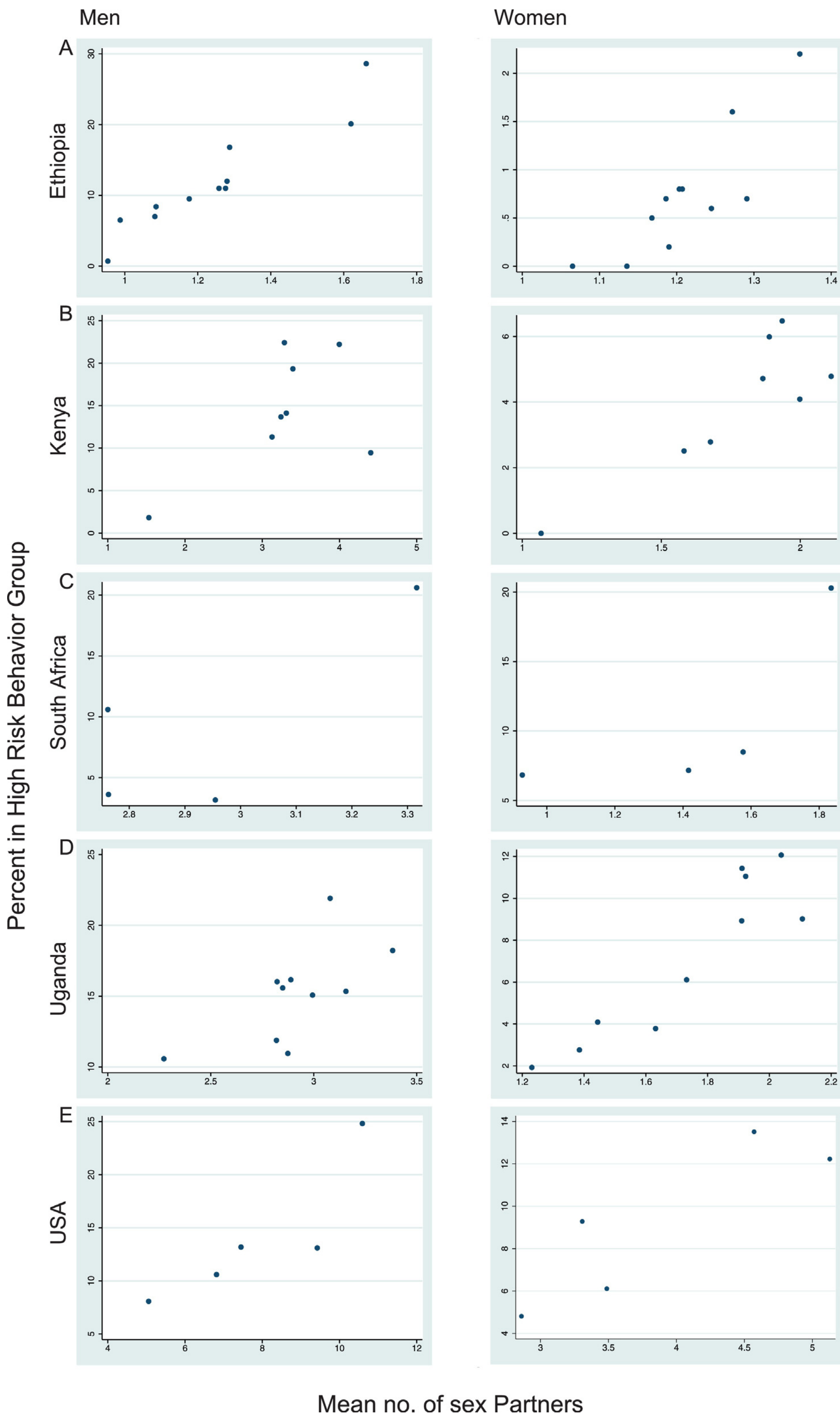

Fig. 2. Association between prevalence of higher-risk behaviour (defined in Section 2) and mean number of lifetime sexual partners (mean calculated excluding all those in the higher-risk behaviour group) in men (left) and women (right) by region/race/ethnicity in Ethiopia (A), Kenya (B), Uganda (C), South Africa (D) and the USA (E).

Nosek et al., 2009). Of particular relevance to this study, the same flattening of distribution towards favouring norms more tolerant of multiple partnering in high versus low HIV prevalence ethnic groups was found in a study from South Africa (Kenyon et al., 2014a).

Although not formally tested, the distribution of number of sex partners appeared by inspection to approximate that of a Poisson distribution. In keeping with this, we found (with a few exceptions) a positive association between the mean number of partners and the variance thereof (Anderson, 1991; Anderson and May, 1988).

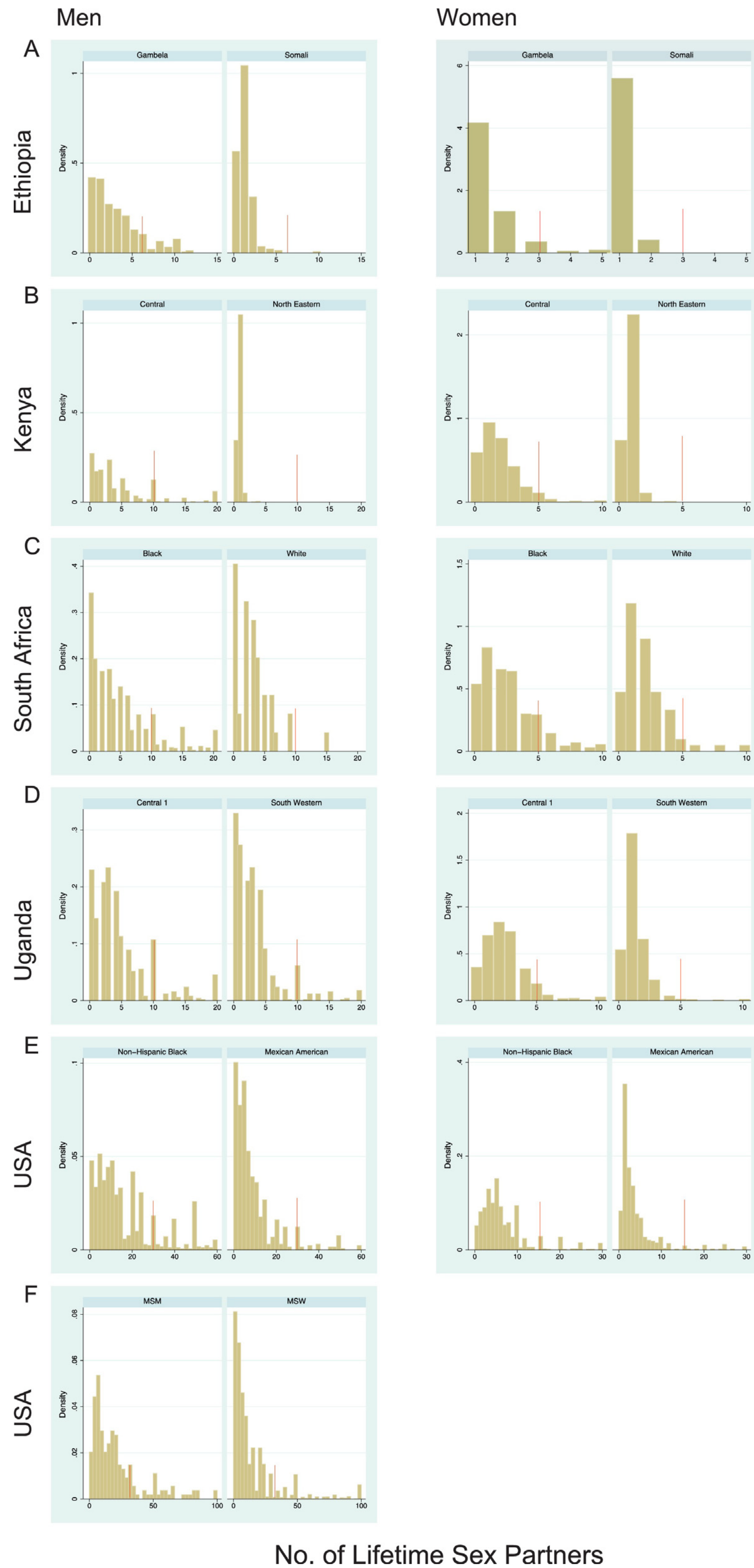

Fig. 3. Normalized histograms of the distribution of lifetime number of sex partners in men (left) and women (right), in lower-risk and higher-risk sub populations in Ethiopia (A), Kenya (B), South Africa (C), Uganda (D), USA—ethnic groups (E), USA—Men who have sex with women (MSW)/Men who have sex with men (MSM) (F). The vertical red line indicates the threshold for entry into the high-risk behaviour category for each country by gender. The *X*-axis (number of sex partners) is cut at twice the high-risk behaviour threshold.

Table 2
Results of the two-sample Wilcoxon rank-sum test assessing if there was a difference in the median number of lifetime partners between the lowest and highest-risk ethnic groups in each country.

	Median no, of sex partners—excluding those in HRB (*P*-value)[a]						Median no, of sex partners—including those in HRB (*P*-value)[a]					
	Men			Women			Men			Women		
	Lowest-risk	Highest-risk	*P*-value	Lowest-risk	Highest-risk	*P*-value	Lowest-risk	Highest-risk	*P*-value	Lowest-risk	Highest-risk	*P*-value
Ethiopia	1	1 (0.000)	***	1	1 (0.192)		1	2 (0.000)	***	1	1 (0.000)	***
Kenya	1	3 (0.000)	***	1	2 (0.000)	***	2	3 (0.000)	***	1	2 (0.000)	***
South Africa	3	3 (0.608)		2	2 (0.879)		3	4 (0.800)		2	2 (0.002)	
Uganda	2	3 (0.000)	***	1	2 (0.000)	***	2	4 (0.000)	***	1	2 (0.000)	***
USA (Ethnic groups)	5	9 (0.000)	***	2	5 (0.000)	***	5	12.5 (0.000)	***	2	5 (0.000)	***
USA (MSM/MSW)	8	11 (0.000)	***	–	–		6	22 (0.000)	***	–	–	

HRB: higher-risk behaviour group.
[a] For interquartile ranges please see Table 1.
*** *P*-value: <0.0005.

This has important consequences. Increasing deviance in number of partners plays an important role in the spread of STIs (Cooke and Yorke, 1973; Hethcote and Yorke, 1984). This makes more salient the finding that mean lifetime partners is associated not only with prevalence of the HRB but also with the magnitude of variance. Population reductions in mean number of partners may therefore impede STI spread via reductions in both the size of the HRB and in the variance in number of partners.

There are a number of limitations to our analysis. Sexual behaviour, and especially that collected from Demographic and Health Surveys, is prone to respondent biases (Morris et al., 2013; Phillips et al., 2010). It is possible that the lower risk populations were more influenced by this bias. The lower risk populations may, for example, differ from the higher risk population not in their lifetime number of partners but only in the extent to which they underestimate these due to a social desirability bias. However, we found no evidence in the literature to support this assertion. Furthermore, the results obtained via ACASI – shown to minimalize respondent bias (Beauclair et al., 2013) – were very similar to those obtained by direct interviews in respect to the degree of difference in lifetime partners between the higher and lower-risk groups. The numbers of whites and Indians in the South African survey were small, making estimates relating to these groups unstable. It should be noted that other studies using representative samples of all South Africa's racial groups found large differences in sexual behaviour, such as number of partners in the prior 12 months (Kenyon et al., 2009, 2013a). These differences were congruent with those found in this study. We found a consistently positive association at a population level between the number of partners and HIV prevalence although this was rarely statistically significant. HIV prevalence is influenced by factors over decades and longer (Kenyon et al., 2013b). As such we should not over-interpret cross sectional studies relatively late in the HIV epidemics of these countries (Kenyon et al., 2013b). The average lifetime number of partners is influenced by both age at sexual debut and current age structure of the sampled population. Although we used age standardization to control for the latter, we did not control for the former, and this may have influenced our results.

Our conclusions are supported by the robustness of our findings: results were similar in a wide range of different countries and were similar whether comparing ethnic groups or men with different sexual orientations. The results were also similar whether the data was acquired via ACASI or direct interviews.

Preventive strategies typically focus on identifying and attenuating the behaviour of those in the minority with the highest risk behaviours (the high-risk strategy), without disturbing the rest of the population (Rose and Day, 1990). However, if our findings of a close relationship between the mean and the high-risk tail are true, then reducing the tail without addressing the mean may be difficult or impossible to achieve (Rose, 1993b). A complementary strategy to the high-risk strategy is the population strategy, which seeks to address the factors responsible for the increase in mean risk behaviour (Rose, 1993b).

More research is required to examine the extent to which social, economic and cultural factors determine the differences in distribution of risky sexual behaviour. Human sexual behaviours are influenced by a range of structural, voluntarist, contingent and other factors and are susceptible to swift change (Christensen and Gregg, 1970; Kirby, 2008; Kenyon and Zondo, 2011; Harmer-Dionne, 1998; Mahay et al., 1994). Assessing what underpins these differences is vital before one plans interventions. In areas where socioeconomic factors are important (Kraut-Becher et al., 2008; Krieger et al., 2003; Laumann and Youm, 1999), these should be addressed (Morris et al., 2009; Kenyon and Zondo, 2011). In other areas, where cultural factors predominate (Kenyon et al., 2014b, 2014c; Jana et al., 2008), more research is needed to establish the optimal strategies to engage populations to attenuate risky sexual behaviour (Knopf et al., 2014). However, several successful interventions from Uganda provide hope for the potential efficacy of culturally appropriate, population strategies: a recent randomized controlled trial used community mobilization to successfully reduce self-reported rates of multiple partnering (Abramsky et al., 2014), and the 'Zero grazing' campaign that used a word of mouth strategy to disseminate sexual behaviour change through social networks resulted in rapid and important reductions in the proportion of men and women reporting non-regular sexual partners (Low-Beer and Stoneburner, 2003).

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

CK conceived the study, and participated in its design and coordination and drafted the first version of the manuscript. IS and AT participated in the design of the study and the statistical analysis. All authors read and approved the final manuscript.

Ethics approval

This research involved secondary data analysis of five surveys that each received ethical committee clearance for data analyses such as the one performed here. All data is aggregated to the level of communities preserving anonymity. No additional ethics committee approval was sought for this study.

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