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Social determinants of adult sex ratios and racial/ethnic disparities in transmission of HIV and other sexually transmitted infections in the USA

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In Black population centres in the USA, adult sex ratios (ASRs) are strongly female-biased primarily due to high male incarceration and early mortality rates. I explore the system of social determinants that shape these ASRs, and describe their apparent consequences. Evidence suggests that female-biased ASRs play a role, along with racial residential segregation, to increase mixing between core and peripheral members of sexual networks, facilitating transmission of human immunodeficiency virus and other sexually transmitted infections. Unique historical factors underlie Black male incarceration and mortality rates in the USA, making comparisons with other groups or other countries challenging.

This article is part of the themed issue 'Adult sex ratios and reproductive decisions: a critical re-examination of sex differences in human and animal societies'.

1. Introduction

For investigators of human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) and other sexually transmitted infections (STIs) in the USA, racial/ethnic disparities in incidence and prevalence have suggested a complex interplay of risk behaviours, geography and social determinants related to poverty and discrimination [1–3]. Female-biased adult sex ratios (ASRs) among the non-Hispanic Black/African American (hereafter referred to as Black) population in the USA have been studied in relation to low marriage rates and perceived social disorder [4–10]. Qualitative research during the 1990s and 2000s suggested that some Black men and women perceived that women were disempowered in their heterosexual relationships with men because relatively few men were available to them for potential romantic relationships or marriage [11–14]. More recently, quantitative analyses have shown ASRs to predict the numbers of opposite sex partners (sexual partnerships consisting of a man and a woman), partner concurrency, and HIV/STI incidence, although results have not been entirely consistent [15–19].

Historical demographic research suggests that national and regional ASRs can become unbalanced due to wars, sex-selective migration and extreme environmental conditions [20]. Recent advances in ultrasound technology have also enabled sex-selective abortion, resulting in more male-biased sex ratios at birth in some areas, particularly in Asia [21]. In addition to early mortality, male scarcity arises in contemporary US Black population centres due to high rates of male incarceration [15,22–24]. Census data show that the national ASR in the US Black population has been female-biased since at least 1850 [25]. The ASR reaches its highest recorded level, 99.2 men per 100 women (0.498 or 49.8% male), in 1920, it has been lower than 95 (0.487) since 1950 [25].

As shown in table 1, the overall ASR can mask unbalanced ASRs in racial/ethnic minority groups. While the overall national ASR in the 15–49 age group is nearly balanced, ASRs for the non-Hispanic White (hereafter referred to as

Table 1. ASRs (calculated as the ratio of men per 100 women and as the proportion male) calculated at the national level using Census 2010 data males and females in the 15–49 age group by racial/ethnic group, and adjusted for the populations in adult correctional facilities (except where noted). *Note*. Data are from the 2010 Decennial Census, except for Black residents of Philadelphia, PA, 1890, which is from Du Bois [26,27].

	unadjusted		adjusted for the populations in state and federal prisons	
population	ASR (ratio)	ASR (prop. male)	ASR (ratio)	ASR (prop. male)
total	100.98	0.502	99.34	0.498
non-Hispanic White	101.73	0.504	100.74	0.502
Hispanic	107.86	0.519	106.10	0.515
non-Hispanic Black	93.38	0.483	88.34	0.469
non-Hispanic Black residents of Philadelphia, PA	83.80	0.456	82.27	0.451
Black residents of Philadelphia, PA (1890, ages 15–45)	89.24	0.472	—	—

White) and Hispanic populations are male-biased. By contrast, the Black population ASR is female-biased. Hispanic ASRs are strongly male-biased primarily due to male-biased Hispanic immigration to the USA [28]. Below, known or presumed causes and consequences of unbalanced sex ratios in the USA are described in greater detail.

(a) Methods

To make observations about ASRs in different racial/ethnic groups in the USA, Census 2010 data disaggregated at the county level, and national surveillance data, mortality data and population-based survey data are used below where possible [26]. For comparability with previous research in the US ASRs are calculated as the number of men per 100 women in the 15–49 age group, after removing the populations estimated to be living in state or federal prisons. For comparability with international research, ASRs are also expressed parenthetically as the proportion male (number of males / (number of males + number of females), using the same age range and removing prisoners).

2. Causes of unbalanced adult sex ratios in the USA

(a) Unbalanced sex ratios at birth

The sex ratio at birth in the US Black population is less male-biased than that of the White population [29]. While the national sex ratio for Black births has increased in recent decades, it is still substantially lower than that for White births [29]. In 2014 the Black sex ratio at birth was 102.9 (0.507), while that for Whites was 105.1 (0.512) [30]. Thus, the sex ratio in the Black population begins to differ from that of the White population at birth, and perhaps prenatally. Some evidence suggests that higher Black single-parent birth rates, lower socioeconomic status, and stress related to discrimination may partly explain this disparity, given that stress is more likely to harm or lead to the prenatal death of males than females [31,32]. It is unclear to what extent the less male-biased sex ratio at birth in the Black population contributes to the female-biased Black ASR.

(b) Excess male mortality

Despite large decreases in death rates and increases in lifespans from the nineteenth century to the present, the mortality gap between Black and White populations in the USA have remained wide [33]. Black infant, neonatal and postnatal mortality rates far exceed those of Whites and most other racial/ethnic groups [34]. Stress related to poverty and discrimination may contribute to infant mortality, particularly for boys [35–37]. Human males exhibit greater mortality than females throughout the lifespan for biological and social reasons [31]. Death rates among US Black males appear to impact Black ASRs. Figure 1 shows the death rate ratios for men versus women by age category and racial/ethnic group [39]. As can be seen, death rates for men exceed those for women in all age categories and racial/ethnic groups. Male–female death rate ratios of Blacks greatly exceed those of Whites in the 15–29 age range, with that for Blacks peaking at 3.30 in the 15–19 age range. The male–female death rate ratio for Whites peaks at 2.95 in the 20–24 age range.

The main cause of differences in death rates between adolescent and young adult males who are White and those who are Black is the differential homicide rate. Homicide is the leading cause of death for Black males ages 15 through 34, while homicide is the third leading cause of death for White males aged 15–24, and the fifth leading cause of death for White males aged 25–34 [38]. The age-adjusted death rate for homicide among Black males was 32.3 (per 100 000) in 2014, while it was 3.3 for White males and 7.2 for Hispanic males [39]. Homicide death rates among women are lower and more similar across racial/ethnic groups. In 2014, the homicide death rate for Black females was 4.8, while that for White females was 1.6, and that for Hispanic females was 1.7 [39].

HIV disease, which was among the leading causes of death among young adults overall in the late 1980s/early 1990s, has receded in recent years due to effective antiretroviral medication [40]. Even so, HIV disease remains among the top six leading causes of death for Black males across ages 20–54 [38]. For comparison, HIV disease is a leading cause of death for White males in only two age categories (ninth among those aged 35–44 and 10th among those aged 45–54).

(c) Military service

Military service generally removes individuals from their residential locations for the duration of their service, which can contribute to lower ASRs in those locations and higher ASRs around military bases. Black male enlistment in US

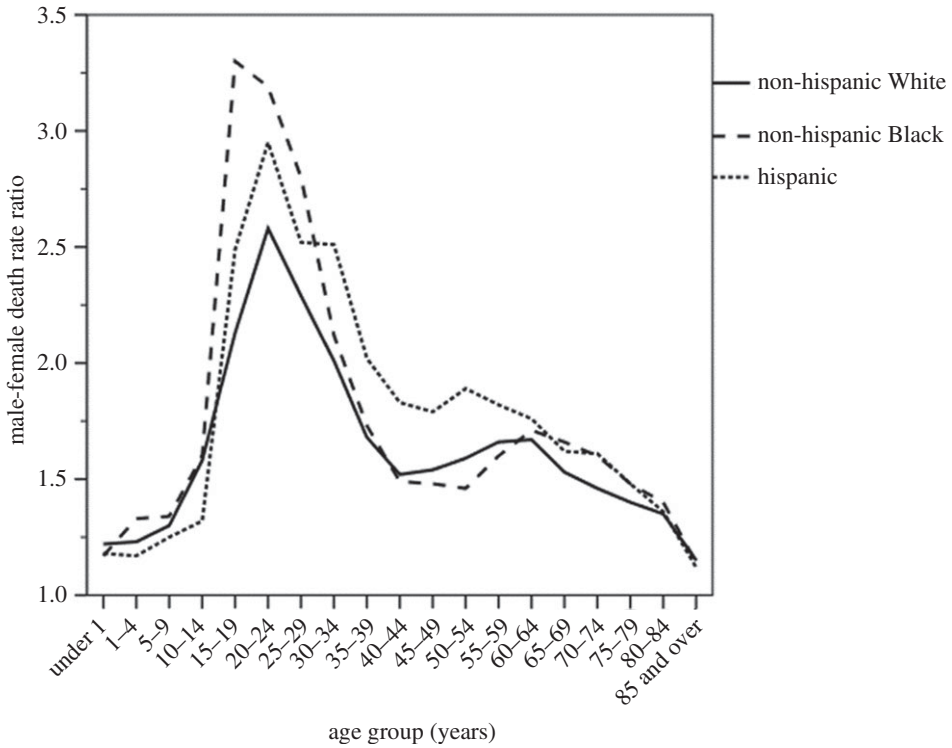

Figure 1. Male–female death rate ratios by age category and racial/ethnic group. Note. Data are from National Vital Statistics Reports [38].

military service has declined since the early 2000s, but Black men remain slightly overrepresented in the military [41,42]. Black individuals represent about 13% of the US general population, and just under 17% of Active Duty members [26,41]. By contrast, Black women's enlistment in military service has grown substantially in recent years, and Black women now make up about 30% of women in the US military [43]. Women make up about 15% of Active Duty members [41]. Roughly 1.2% of the total Black population aged 15–49 years are Active Duty members.

(d) Non-heterosexual identity

It is possible that the presence of large gay communities may bias ASRs. It may be inferred that large cities can attract gays and lesbians, with some, such as New York, acting as gay enclaves. Individuals who are gay or lesbian (as well as individuals who are not sexually active or who are in mutually monogamous relationships) generally are not active in heterosexual sexual/romantic markets. There may be differences in the proportions of men and women who are gay or lesbian by race/ethnicity; however, there are few reliable population estimates of these groups. With little data other than proportions based on self-reports from surveys, it may be reasonable to assume a roughly equal proportion of gay men and lesbians within each racial/ethnic group.

(e) Employment-related migration

In urban areas, the ASR can reflect employment opportunity differences between men and women. This was observed by W.E.B. Du Bois in the first sociological study of Blacks in the USA, originally published in 1899 [27]. In this seminal work, Du Bois conducted a survey and census of Black residents of Philadelphia, Pennsylvania. He noted: 'Scanning this population more carefully, the first thing that strikes one is the unusual excess of females. This fact, which is true of all Negro urban populations, has not often been noticed, and has not been given its true weight as a social phenomenon' (p. 53). Table 1 shows the ASR for this population. He goes on to describe that: 'The cause of this excess is easy to explain. From the beginning, the industrial opportunities of Negro women in cities have been far greater than those of men, through their large employment in domestic service' (p. 54). The differences in employment opportunities between Black men and women were apparent even while slavery was ongoing. Slavery is documented in Pennsylvania as early as 1639 [44], and was abolished over the late eighteenth/early nineteenth centuries after the passage of the Pennsylvania Gradual Abolition Act (1780) [45]. Du Bois explains that restrictions on employment of free Black men in Philadelphia, beginning in 1820, remained in force during the 1890s, and: 'The proportion, therefore of men to women is a rough index of the industrial opportunities of the Negro' [27, (p. 55)]. Thus, to Du Bois, female-biased ASRs among Black residents of urban areas reflected a system of racial discrimination, targeted more intensely at men.

The potential effects of employment discrimination on internal migration and contemporary Black ASRs are less clear. Although racial discrimination in housing and employment were prohibited by the Civil Rights Act of 1964 [46] and the federal Fair Housing Act of 1968 [47], evidence suggests that these forms of discrimination remain prevalent [48–50]. In the USA, counties and states where Black populations are relatively small (e.g. New Hampshire, Washington, North Dakota) tend to have strongly male-biased Black ASRs. However, these states do not systematically have higher than average Black employment rates [51]. Nationally representative American Community Survey data show that about 4.3% of Black individuals and 3.9% of White individuals move to a different county or state in a given year, with little difference between males and females [52]. However, most of these moves are housing-related rather than job-related, with Blacks

moving more often for housing (52.7%) and less often for employment (15.1%) than Whites (46.8% and 19.7%, respectively) [53]. At the same time, recent research suggests that Blacks who move between the North and South enjoy significantly higher gains in relative social position than Whites making the same moves, even though they do not make absolute employment gains [54].

Genders are relatively balanced among African migrants to the USA, with men slightly outnumbering women [55]. With migration rising sharply since 2000, over 1.8 million African immigrants are currently living in the USA [56].

(f) Mass incarceration

The high rate of incarceration (mass incarceration) in the USA has been characterized as a form of 'forced migration' [57,58] or 'coercive mobility' [59]. Over half a million Black men were in state or federal prison in 2014, representing 37% of all male prisoners [60]. This does not include jail populations that typically house inmates with sentences shorter than 1 year. As of 2001, 1 in 3 Black males in the USA could expect to become incarcerated during their lifetimes, compared with 1 in 17 White males [61], although these rates may have declined since the national incarceration rate peaked in 2009 [62]. Blacks at every level of wealth are more likely to become incarcerated than Whites or Hispanics [63]. Youth from affluent Black families have about the same likelihood of becoming incarcerated as youth from the poorest White families [63].

The extent to which the high rate of incarceration among Black men affects ASRs is evident when comparing total US population ASRs with those calculated after removing the prison population. Using Census 2010 data, table 1 shows that the national Black population ASR was only 93.38 (0.483) in the 15–49 years of age range, but is 88.34 (0.469) after removing the estimated male and female populations in prisons. Most prisons are not located in urban areas. In fact, in many states' prisoners are often incarcerated in locations hundreds of miles from their homes [64]. This has the effect not only of destabilizing the family connections of those imprisoned, but also of transferring political power from urban minority areas to rural non-minority areas. Prisoners are counted by the Census as residing in the locations of the prisons, and these data are used to apportion political representation [65,66]. For example, because there are relatively few prisoners in Philadelphia, removing them from Census data results in an ASR in the Black population that is only slightly lower (82.27 [0.451]) than that including prisoners (83.80 [0.456]).

Notably, of the approximately 173 000 non-incarcerated Black women in this age range in Philadelphia in 2010, about 1 in 6 (17.7%; over 30 000) did not have a non-incarcerated male counterpart in the city.

However, since the early 2000s some states and the Federal Government have reformed sentencing guidelines and related policies. These reforms will potentially lead to lower overall prison populations and potentially to more balanced Black ASRs. For example, the Fair Sentencing Act of 2010 reduced mandatory minimum sentences, and reforms of New York State's Rockefeller drug laws reduced incarceration rates by 26% [67,68]. The national incarceration rate and the national homicide rate have both fallen from their peaks in the 1990s and 2000s [62,69].

3. Consequences of unbalanced adult sex ratios in the USA

The study of sexual and reproductive behaviour among the Black US population is greatly complicated by the abusive history of medical and scientific research on Blacks during the eighteenth, nineteenth and early twentieth centuries. Most scientific writing about Blacks during this period included biased and false reports intended to justify slavery and subjugation [70]. More recent examples, including the Tuskegee Syphilis Study, which denied treatment and accurate health information to poor rural Black sharecroppers even after penicillin was validated as a treatment for syphilis, have led to deep and somewhat warranted suspicions of medical and scientific researchers [71]. In describing associations of ASRs, it is important to ensure that the dignity and agency of people in historically oppressed minority groups are respected. The decisions to enter into and maintain sexual and romantic partnerships are based on complex factors that may have little or nothing to do with ASRs. Nonetheless, ASR effects may be more pronounced for people in minority groups than others (due to assortative partnering and segregation, described in §4).

The female-biased ASR in the Black population does not represent excess women; rather, it represents men who are not present, evidence suggests, largely because they have died prematurely or have been imprisoned. The scarcity of Black men can affect the relative bargaining power of women and men in heterosexual relationships, and can affect rates of marriage and cohabitation, and sexual network composition and STI transmission. These consequences are described in greater detail below.

(a) Social exchange, and gender and power theories

Male scarcity is hypothesized to effect heterosexual behaviour by impacting dyadic power in male–female partnerships [20]. The idea that the ASR can help to shape sexual relationships is consistent with Social Exchange Theory, which suggests that satisfaction with relationships depends on prior expectations, comparison with alternatives, and investments made in the relationship [20,72,73]. These evaluations may or may not be made explicitly. Applied to sexual relationships, Social Exchange Theory is modelled on an economic market where individuals seek sexual and romantic partners, and dyadic sexual partnerships exist as part of a loosely integrated market with other individuals and dyads [74].

In this regard, Social Exchange Theory can be contextualized by considering the Theory of Gender and Power, which describes the power imbalance that occurs at different levels of social organization including families, institutions, workplaces, communities, cultures and societies [75–77]. Major social structures that characterize relationships between men and women are the sexual division of labour, the sexual division of physical and psychological power, and the structure of intimate relationships, including social behavioural and relationship norms. In addition, gender asymmetry in prostitution, cultural suppression of female sexuality, rape and sexual attitudes reflect complementary economic roles for men and women [76]. Potential male–female differences in motivations and efforts required to be in a relationship may be enhanced by social and cultural systems that limit alternative means for women to obtain resources [76]. In this

context, a scarcity of potential male partners can be viewed as operating according to laws of supply and demand to further increase the bargaining power of men and further reduce the bargaining power of women in male–female partnerships.

(b) Low rates of marriage or living as married and non-marital births

In the USA, people who are married or living as married are less likely to have multiple and concurrent sex partners than those who are not [78,79]. Thus, high rates of marriage or living as married can be protective against HIV/STI transmission, assuming they indicate more monogamous partnerships [80]. By contrast, in countries where women are likely to be infected by their husbands, being married can increase the risk of HIV/STI acquisition for women [81].

Female-biased ASRs have been found to be associated with the relatively low marriage rate and the relatively high non-marital birth rate in the US Black population [4–9,82–84]. Non-marital birth rates have increased for every racial/ethnic group since the 1960s, but have been consistently higher for the Black population [30,85].

(c) The number of sex partners

While condom use can prevent HIV and STI transmission, the number of sex partners is a key indicator for transmission potential [86,87]. Research suggests that in the USA condom use drops precipitously in new sexual partnerships after about three weeks [88]. Although people who are aware they are HIV-positive tend to use condoms consistently with their uninfected partners, many HIV-positive individuals are unaware of their HIV status [89].

National data on the numbers of sex partners by gender and race/ethnicity are consistent with female-biased ASRs leading to increased numbers of female partners for men on average, and increased variation in the numbers of male partners for women. Nationally representative data from the National Survey of Family Growth show that more Black women (3.2%) than White women (2.9%) reported four or more male sex partners during the past year [90]. At the same time, more Black women (9.5%) than White women (5.5%) reported no male partner during the past 12 months (but having had sex with a man more than 12 months ago, and thus potentially being active in the local sexual/romantic partnership market). By contrast, data from men are consistent with female-biased ASRs enabling men to accrue more female sex partners on average. More Black men (10.8%) than White men (5.5%) reported four or more female sex partners during the past year, and fewer Black men (4.7%) than White men (6.5%) reported no female partner during the past 12 months (but having had sex with a woman more than 12 months ago) [90]. Although self-reported data on the numbers of partners have been found to contain multiple sources of bias, the relative differences among racial/ethnic groups and between genders have been shown to be fairly consistent [79,91,92].

(d) Sexual network composition

A social network represents interactions between and among people. A network of sexual contacts is an example of a social network [93]. Social network theory has been key to understanding HIV/STI transmission and epidemiology. Research suggests that people have relatively little control over their position in a social network; rather, networks arise from geographic, cultural and familial contexts in the place of residence [94]. Social networks tend to be homophilous (i.e. populated by people with similar characteristics or interests), and tend to be so for race/ethnicity, age and other characteristics [95,96]. Uninfected members of sexual networks that have a high infection prevalence carry substantial risk for becoming infected themselves [97,98].

Individuals with many sex partners are at the core of a sexual network, while individuals with only one sex partner can be described as being on the periphery [99]. Core individuals are more important than peripheral individuals and the number of core members is more important than the average number of sexual partners for HIV/STI transmission because core members contact and expose more people to infection while they are infectious [87]. Overlapping or concurrent partnerships also carry great potential for HIV/STI transmission because new infections can be spread rapidly to uninfected concurrent partners [100].

In a nationally representative survey, Laumann and colleagues found that '…even though African American peripheral people have, by definition, only one partner, the chance that their partners are in the core is five times higher than it is for White peripheral people…' [101, p. 260]. They explain that Blacks in the USA necessarily have higher infection rates than Whites or Hispanics because prevalence is higher in the Black population, and infections are transmitted from individuals in the core of sexual networks to individuals at the periphery due to strongly racially assortative mixing (sexual partnerships between members of the same race; described in §4a). Female-biased Black ASRs in the county of residence are associated with more Black men having five or more female partners in the past year, which is one definition of being a core network member [15]. In addition, women in female-biased ASR counties can experience adverse selection, with potential male partners having more HIV/STI risk characteristics on average [18].

(e) Incidence of HIV/STIs and the numbers of sexual partners

Incidence rates of HIV and several other STIs are estimated to be higher among Blacks than among other racial/ethnic groups [102]. Research suggests that the scarcity of Black men in the USA is part of the causal chain that leads some to accrue more female partners, with increasing numbers of core network members facilitating HIV/STI transmission [15,103].

Several ecological studies have compared ASRs or incarceration rates with HIV/STI surveillance data, with some finding significant associations [19,104–107]. However, ecological studies may be vulnerable to ecological inference fallacy (wherein trends observed at the aggregate level can differ from those at the individual level), incomplete control for confounding and multicollinearity.

Some studies have used sexual behaviour (i.e. the number of partners or partner concurrency) as a proxy outcome in research on potential effects of ASRs and incarceration rates. Significant associations have been observed in qualitative studies [13,17,108,109], computational modelling [110] and geographically nested individual-level studies [16,18]. Independent effects of incarceration rates and ASRs have also been demonstrated, although these analyses are

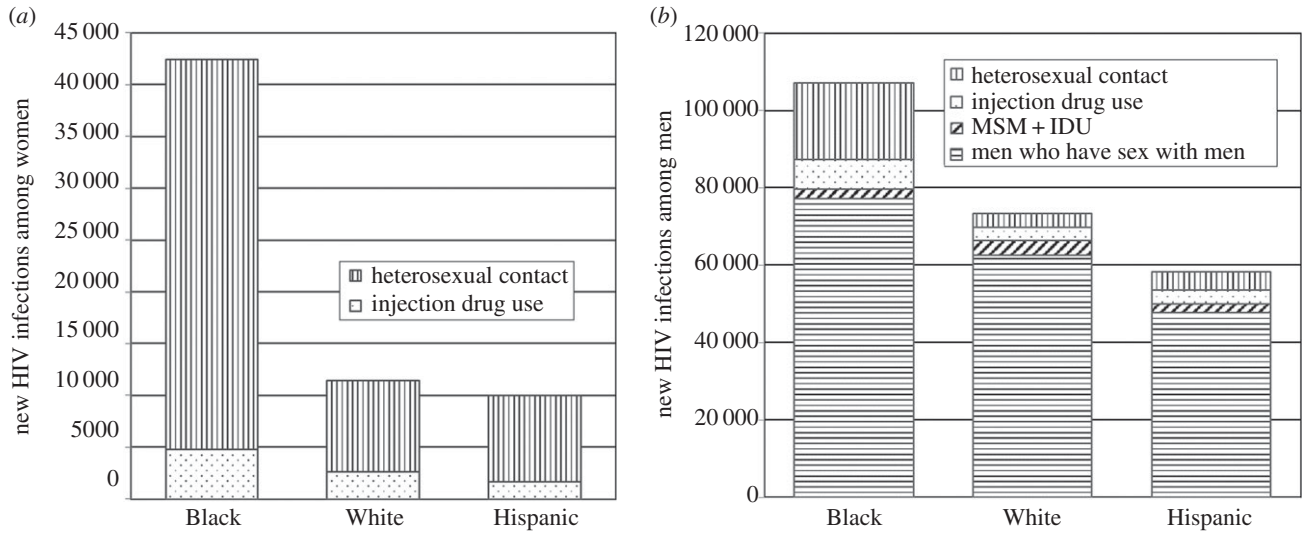

Figure 2. Estimated number of US HIV infections among (*a*) women and (*b*) men of selected racial/ethnic groups by transmission category, 2008–2014. *Note*. Data are from HIV Surveillance Reports [111–117]. Excludes data from other and unknown racial/ethnic categories, and excludes data from other transmission categories and risk factor not reported or identified.

complicated by the lack of control for the rate and locations of prisoner release [59].

Although national surveys are not designed to assess ASR-related hypotheses, comparisons with national HIV incidence data may be informative. As shown in figure 2, most HIV infections among women are attributed to heterosexual contact, and more than twice as many Black women have been infected through heterosexual contact than White and Hispanic women combined in recent years. More Black men also have been infected through heterosexual contact than White and Hispanic men combined, but almost twice as many Black women as Black men were infected through heterosexual contact. This pattern is consistent with sexual network structures that put uninfected Black women at the periphery in contact with infected Black men at the core [80]. Further, female-biased ASRs are associated with more Black men being core network members [15]. While the number of new HIV infections has declined substantially in recent years, racial/ethnic disparities among women have remained relatively stable [118].

4. Social contexts that can modify adult sex ratio effects

(a) Assortative sexual partnering

Assortative sexual partnering refers to the tendency for sexual partners to be similar to one another on characteristics that are important to individuals, such as age, race/ethnicity, educational status, religion and place of residence [119,120]. Partnerships between individuals who differ on important characteristics can be described as negatively assortative or *disassortative*. Partnerships between people with similar HIV/STI risk characteristics are risk-assortative, while those between high-risk and low-risk individuals are risk-disassortative. Risk-disassortative partnerships are more likely to transmit HIV/STIs because they are more likely to consist of one infected partner and one uninfected partner.

In racially/ethnically mixed populations, it is important to consider stratifying population data by race/ethnicity to calculate sex ratios. While the rate of interracial partnerships has been increasing since the 1960s [121], most sexual partnerships continue to be assortative by race/ethnicity (partners tend to be of the same racial/ethnic group) [100]. Racially/ethnically assortative mixing restricts HIV/STI transmission within the racial/ethnic groups with high prevalence, and maintains high prevalence through mixing of members of the network core and periphery [93]. At the same time, interracial/ethnic partnerships may be more likely in areas where the ASR is low in one group but balanced or high in another. Research suggests that Hispanic men and women (but not White or Black men or women) residing in counties with female-biased ASRs among racially/ethnically *disassortative* populations are more likely to have had multiple recent opposite sex partners [15]. This may imply that Hispanics in such counties have more ethnically and possibly racially disassortative partnerships, which would be consistent with data showing that sexual partnerships and marriages of Hispanics are more often inter-racial/ethnic than those of Whites or Blacks [122].

(b) Racial/ethnic residential segregation

Racial/ethnic residential segregation probably increases racially/ethnically assortative partnerships. At the same time, this segregation may increase age-disassortative and educationally-disassortative partnerships, which may also represent *risk*-disassortative partnerships. Evidence suggests that Blacks tend to live in segregated Black neighbourhoods in part due to active discrimination in housing, employment and lending [123]. Middle-class Blacks are more likely to live in poor Black neighbourhoods than middle-class non-Black neighbourhoods [124]. Sexual network research suggests that Blacks in the USA living in segregated neighbourhoods have more risk-disassortative partnerships, i.e. those involving high-risk (individuals who have many other partners) and low-risk partners (individuals with only one or few other partners) [101].

ASR effects may interact with segregation and population size in complex ways. For example, White women who live in a county with a female-biased ASR can respond by

considering the pool of available partners in a bordering county. However, due to the relatively smaller Black population size and residential segregation, Black women cannot respond the same way because bordering counties are less likely to have substantial Black populations. Census 2010 data show that only 842 of 3143 US counties (27%) had 1000 or more Black females and 1000 or more Black males in the 15–49 age range after excluding prisoners, while the number for Whites was 2654 (84%) [26].

5. Challenges to analyses of associations between ASRs and sexually transmitted infection rates

A number of methodological issues complicate the analyses of ASRs and their potential relationships with HIV/STI transmission.

(a) Measurement challenges

Geographic boundaries for ASR calculations are somewhat arbitrary approximations. The county has been used successfully in research on sexual behaviour and HIV/STI transmission [16,84,125]. Metropolitan areas, defined to represent areas of work and residence, may also be good proxies [126]. However, these measures assume individuals have equal access to transportation throughout the county or metropolitan area. Some counties or metropolitan areas have good access to other counties, and may even be in walking distance, facilitating partnerships across borders. Larger areas, such as states or nations are less likely to well-represent the partner-seeking locations of individuals; however, ASRs calculated at these levels may serve as good proxies under some conditions. Studies using ASR calculations based on smaller areas, such as neighbourhoods or Census Tracts have also found significant associations with HIV/STI transmission, but less consistently, possibly because these areas incompletely represent the areas wherein most individuals seek partners [127,128].

Increasingly, online dating may make the local ASR less relevant for partner-seeking. This may not improve the male partner-seeking situation for Black women because data suggest that they are more highly excluded in online dating than women of other racial/ethnic groups or Black men [129]. This research shows that Asian Indians, Middle Easterners and Asian men are also highly excluded.

It is unclear which if any populations in group quarters (including correctional facilities, student housing, residential treatment centres and military barracks) should be included when calculating ASRs. It may be reasonable to exclude prisoners given that they are usually imprisoned for sentences of longer than 1 year, often in prisons that are distant from the location of their last residence. Jail inmates in contrast are usually sentenced for less than one year and are housed near where the criminal offenses were committed.

(b) Analytical challenges

Quantitative analyses of associations of ASRs in the USA are challenging for several reasons. These may include sampling or enumeration problems, intercorrelations among determinants as well as outcomes, indirect and nonlinear effects, relatively low HIV/STI incidence and the unique historical aspects of determinants of ASRs in the Black population.

ASR effects have been found to be non-monotonic and nonlinear [15,105]. The fact that ASR effects may vary in magnitude or even direction in differing social contexts may account for some of the inconsistent findings across studies and across geographic areas. Several sources of measurement error may also contribute to this nonlinearity or non-monotonicity. US Census data are estimated to undercount Black men more than other men because they are more likely to live alone [130–132]. This enumeration error appears to be relatively slight, but may serve to reduce associations of ASRs with sexual behaviour or HIV/STI incidence. A related problem—non-response—may complicate population-based surveys, if men who live alone participate at lower rates. Men with the most sex partners may also have other characteristics, such as being an ex-offender, that make them less willing to participate in survey research [133,134]. Small racial/ethnic representation in some counties, which will occur by definition among minority groups, further complicate inferential statistical analyses [135]. In addition, people may move in response to adverse ASRs, and highly sexually active individuals may not be well captured by population-based sampling methods [136].

Another challenge to assessing the independent effects of incarceration rates and ASRs on HIV/STI outcomes is the multiplicity of incarceration effects. Besides reducing the ASR, mass incarceration can indicate partnership destabilization on a large scale. Incarceration disrupts the partnerships of both the incarcerated individuals and those of their partners, and can lead to relationship dissolution [137–139]. Individuals may have repeated relationship disruptions or dissolutions due to repeated incarcerations. Incarceration also reduces community assets, paternal supervision, and social capital for children, other family members, communities. Ex-offenders are more likely to engage in risk behaviours post-release, and are more likely to be HIV-infected [137,139]. Having a partner who was recently incarcerated has been associated with having multiple, transactional, concurrent and risky partners, and having had a recent HIV or STI diagnosis [140]. Additionally, ex-offenders are disqualified from many sources of public support and have difficulty finding employment [141]. Further, people convicted of felonies involving the use or sale of drugs are banned from receiving cash benefits or food stamps [142]. These diminished life opportunities may represent barriers to ex-offenders' ability to develop and maintain committed partnerships and marriages.

In addition, it is difficult to isolate the effects of female-biased ASRs on outcomes like HIV/STI incidence in the USA because two main causes of female-bias—excess male mortality and mass incarceration—affect the Black population disproportionately, and have other outcomes that themselves may increase HIV/STI transmission. Historical evidence suggests that mass incarceration has served in part to prevent Black social and economic integration [66,143]. Recent research has examined how criminal policy and the reliance on discretion throughout the criminal justice system from arrest to post-release supervision is sometimes racially biased [66]. Yet, a criminal history authorizes discrimination and political disenfranchisement, with limited rights to employment, housing, voting, serving on juries and receiving government benefits [66,141,144,145]. Chronically high incarceration rates contribute to shaping the electorate so that it fails to fully

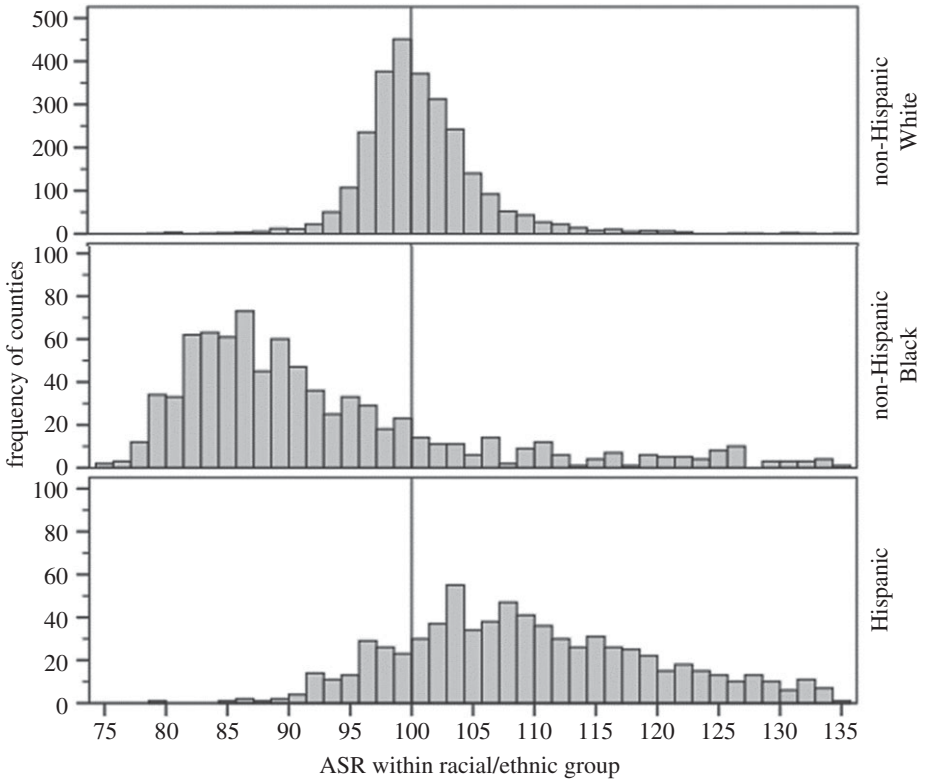

Figure 3. Histograms of US county adult sex ratios for non-Hispanic White, non-Hispanic Black and Hispanic populations. *Note*. ASR, adult sex ratio (men per 100 women). ASR range is truncated to display the most frequent values. ASRs are calculated for counties with 1000 or more men and 1000 or more women in the 15–49 age group in the target racial category, after excluding prisoners using 2010 Decennial Census data [26]. Note that the scale for the non-Hispanic White population is 500 while that of the minority populations is 100 because there were fewer counties with minority populations. ASRs of 75, 100 and 135 are equivalent to male proportions of 0.429, 0.500 and 0.574, respectively.

represent the population, making it less likely that elections will result in mandates to reduce racial/ethnic inequality [146]. The absence of imprisoned men translates to fewer resources for their families and fewer community resources [141,147–149], and contributes to ongoing and intergenerational poverty [64,150]. Black fathers are involved in parenting roles with their children at rates comparable to those of Hispanic and White fathers [151]; however, female-headed households without an involved father may be less stable, with worse child developmental outcomes [152,153].

One useful way to think about correlated social determinants and HIV/STI-related outcomes is using the 'syndemics' framework [154]. Syndemics are defined as two or more diseases or other health conditions that act synergistically, often as a result of social inequality [155]. Focusing on multiple interacting health conditions helps to reveal the causal role of social structural factors on multiple outcomes. Social environmental conditions in disadvantaged neighbourhoods such as poor healthcare, poorly resourced schools, high unemployment rates and high levels of violence and incarceration are associated with higher levels of substance use and AIDS mortality [156–158]. Social determinants often interact to more heavily impact minority groups, constituting a 'double burden' that is not experienced by White residents [159,160].

Overall ASRs may be associated with a number of population factors that are also associated with the percentage of the population that is Black, such as socioeconomic indicators and marriage rates. High incarceration rates can serve as a marker for social factors related to limited economic opportunities for Blacks [27]. High levels of incarceration have been considered possible indicators of social disorder; however, the potential exists for spurious associations because Black race can be a proxy indicator for determinants related to discrimination in housing, employment and lending; disparate criminal prosecution and sentencing; and poor access to quality education and health services [48,66,111,150,161]. Thus, attempting to control for the percentage of the population that is Black statistically can lead to residual confounding [112].

One of the most difficult challenges in assessing the true associations between ASRs with HIV/STI outcomes in the USA is the non-comparability of exposures. Areas with large Black populations tend to have lower overall ASRs, and those with small or no Black populations tend to have more balanced ASRs [26]. At the same time, ASRs above 100 (0.500) can indicate the presence of large Hispanic populations. Table 1 shows the variation in ASRs across racial/ethnic groups. Not only do ASRs vary by race/ethnicity, but to a large extent ASR exposures are not comparable across racial/ethnic groups [15,16,113]. Figure 3 shows the distributions of ASRs for Non-Hispanic White, Non-Hispanic Black and Hispanic populations in counties where at least 1000 men and 1000 women of each respective racial/ethnic group resided. As can be seen in the figure, the modal ASR for White populations is in the 95–100 (0.487–0.500) range, while the modal ASR for Black populations is in the 80–90 (0.444–0.474) range, and that for the Hispanic population is over 100 (0.500). The social environments for Blacks who live in Black population centres are characterized by strongly female-biased Black ASRs. The social environments for Whites are characterized by ASRs that are more balanced, and those for Hispanics are male-biased. Survey research

using population-based random sampling are likely to result in values of ASRs and possibly other area-level exposures that are not comparable across racial/ethnic categories [15,16,113]. In order to assess the same exposure across racial/ethnic groups other methods, such as selecting locations based on matching similar levels of ASRs across racial/ethnic groups, may be needed.

In addition, it may be difficult to separate effects of contemporary ASRs from effects of behavioural norms that may have been shaped in part by historical ASRs [114]. Consistently female-biased ASRs may impact norms regarding marriage and heterosexual partnerships, contributing to a greater acceptance of concurrent sexual partnerships [115,138]. These norms may persist for some time even if ASRs become more balanced [116,117].

International comparisons of female-biased ASRs in large populations are challenging. Strong female-bias is typically the result of war [20]. However, for example, ASRs are female-biased in Mexico due to male-biased migration, and female-biased in Russia due to an unusually high male mortality rate [162,163]. Differences in social contexts as well as in the determinants of ASRs such as these are barriers to generalizing across geographic areas.

6. Conclusion

Evidence has accumulated suggesting that ASRs play a role in shaping heterosexual partnerships and sexual networks to facilitate HIV/STI transmission and increase racial/ethnic incidence disparities in the USA. It is important for researchers and activists to ensure that individuals are informed about their HIV/STI risks and have adequate resources to protect themselves. However, in high-prevalence areas it may also be worthwhile to focus on fundamental social structural determinants of HIV/STI epidemiology [164–166]. The female-biased ASR in Black population centres reflects long-running social problems rooted in chronic anti-Black discrimination going back to the Reconstruction Era [27,66]. Reforms have reduced incarceration rates in some states, which have coincided with a reduction in HIV diagnoses among Black women [118]. Policy changes to further reduce bias in the criminal justice system and in educational settings, and to reduce discrimination in employment, housing and lending, although challenging to achieve, are goals worthy of consideration. Such changes could decrease Black male mortality and incarceration rates, leading to more balanced ASRs and diminished vulnerability to HIV/STI transmission as well as other health and social benefits.

ASR effects in the USA support the mating-market perspective in that female-biased ASRs are associated with men having more partners and having concurrent partners, and women having greater variation in their number of male partners [15,16,90]. However, they also offer some support the sociodemographic perspective to the extent that male-biased ASRs (or less female-biased ASRs) may lead to more men purchasing sex from women [127]. This is somewhat consistent with studies of ASRs and marriage [10,83,84,117], and with studies from other countries [167–169]. Thus, some males and some females may have increased numbers of opposite sex partners under either female-biased or male-biased ASR environments. While the rarer sex may have a comparative advantage, extremes in either direction may be indicators of, or causes of more challenging environments for stable heterosexual relationships and healthy family outcomes.

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