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INVITED REVIEW

Disparities at the intersection of marginalized groups

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Abstract
Purpose Mental health disparities exist across several dimensions of social inequality, including race/ethnicity, socioeconomic status and gender. Most investigations of health disparities focus on one dimension. Recent calls by researchers argue for studying persons who are marginalized in multiple ways, often from the perspective of intersectionality, a theoretical framework applied to qualitative studies in law, sociology, and psychology. Quantitative adaptations are emerging but there is little guidance as to what measures or methods are helpful.
Methods Here, we consider the concept of a joint disparity and its composition, show that this approach can illuminate how outcomes are patterned for social groups that are marginalized across multiple axes of social inequality, and compare the insights gained with that of other measures of additive interaction. We apply these methods to a cohort of young men from the National Longitudinal Survey of Youth, examining disparities for black men with low early life SES vs. white men with high early life SES across several outcomes that predict mental health, including unemployment, wages, and incarceration.
Results and conclusions We report striking disparities in each outcome, but show that the contribution of race, SES, and their intersection varies.

Keywords Disparities · Intersectionality · Interaction · Decomposition · Relative excess risk for interaction · Synergy index · Attributable proportion · Ratio of observed to expected joint effects · Joint disparity · Excess intersectional disparity · Heterogeneity of effects

Introduction

Mental health disparities are avoidable differences in mental health across social categories that many consider unjust, even when their causes are difficult to document or describe [1]. Disparities exist across race/ethnicity, socioeconomic status (SES), gender, and other social categories. Often they are considered separately or with one taking primary focus. For example, efforts to monitor or study race disparities may adjust for gender to remove its contribution. Other efforts might examine race disparities separately for men and women and uncover patterns that emphasize differences by race and not gender [2]. But framing disparities along single axes of social inequality can obscure the excess risk faced by populations at the nexus of multiple marginalized social categories. Because they face multiple social obstacles, such intersected populations may fare much worse than disparities along single axes indicate.

Monitoring and examining the health of multiply marginalized populations is critical for addressing mental health disparities [3, 4]. Strategies to reduce disparities could target multiply marginalized groups, e.g., improving depression screening among low-income mothers of non-native origin. Moreover, interventions might be developed

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and tested in multiply marginalized populations, e.g., an outreach program to improve adherence to HIV medication among depressed men who belong to a racial/ethnic minority group and have sex with men. Such strategies implicitly acknowledge that social categories are not monolithic and attempt to account for the complex ways in which social forces combine to affect health. An intersectional perspective recognizes that social categories are mutually constitutive in that the experience of one social category may differ across other categories [5–7]. For example, indicators of socioeconomic status are not equivalent for whites and ethnic minorities because of pervasive residential segregation [8]: even racial/ethnic groups of the same income and educational attainment live in different environmental conditions. A focus on disparities for one category cannot adequately account for this reality.

Intersectional perspectives have a long history within social justice movements, and are often invoked to critique social activism and policy responses that frame racial and gender oppression as separate issues [5, 9, 10]. Eventually, these critiques were extended by legal scholars to explain how racism, classism, patriarchy, and homophobia form interlocking systems of discrimination [6, 7]. They describe how people experience multiple forms of oppression simultaneously, not piece by piece, with possibly synergistic effects and as altogether unique experiences. In the social science literature, intersectionality studies are typically conceptually rich and qualitative [11]. Recently, researchers have argued that quantitative approaches to intersectionality hold promise for public health as they could inform policy, and also called attention to the scant guidance on which measures and models are appropriate [3, 4, 11, 12]. These reviews recommend appropriating various epidemiologic measures of statistical interaction, regression models with product terms, sometimes within a hierarchical modeling framework. Indeed, some of these methods appear in emerging studies of intersectionality and health [13, 14]. Many of these approaches focus on multiplicative product terms which do not relate to absolute gains in population health that would be achieved by reducing disparities. Moreover, a focus on testing for product terms can detract from communicating the absolute and excess risk faced by multiply marginalized populations, and also from quantifying how each status and their intersection shape these quantities.

Here, we first consider the notion of a joint disparity that compares outcomes for those at the nexus of marginalized categories to those who do not belong to any of those categories. We show how this measure relates to disparities for one category among the non-marginalized category of another, and also an excess intersectional disparity that pertains to the dually marginalized group. We then consider other measures of additive interaction [15] including the synergy index, the attributable proportion, the relative excess risk for interaction, and also the newly proposed ratio of observed to expected joint effects on the relative scale [16]. In an example analysis we apply these methods to describe disparities for young black men with low early life SES, first in unemployment, then in wages and finally incarceration. These outcomes exhibit very large racial and socioeconomic disparities and are, therefore, well-suited to illustrate the proposed method. While these outcomes are not mental health outcomes per se, they strongly predict mental well-being. For example, suicide mortality is higher among economic downturns and associated job loss and stagnated wages [17, 18], and incarceration is associated with tobacco smoking among blacks [19].

Throughout our empirical example we attribute joint disparities (i.e., by race and early life SES) in unemployment, wages, and incarceration to race, early life SES, or their intersection. Because our analysis is restricted to men, it does not consider the contribution of gender (we return to this issue in the Discussion). In attributing disparities to race, we mean the historical legacy of racism in the United States (US) taking shape through various means, including slavery, Jim Crow, and segregation [20]. This legacy involves discrimination which may be intentional or the result of policies, laws or practices that systematically disadvantage blacks and shape economic opportunities [21]. It also involves indirect processes whereby blacks are more vulnerable to economic or political shifts because of this legacy [22]. By attributing disparities to early life SES we mean the economic disadvantage faced by persons in family environments with low income, occupational status, educational attainment, and wealth in accessing desirable resources. By attributing disparities to their intersection, we mean the ways in which racism plays out differently for blacks with low vs. high SES, and also the ways in which economic disadvantage plays out differently for blacks vs. whites.

Example analysis

We used the 1997 National Longitudinal Survey of Youth [23] to investigate racial/ethnic and socioeconomic disparities in unemployment, wages, and incarceration in 2006 and 2007 among a cohort of non-hispanic black and white men born from 1980 to 1984, thus focusing on outcomes in early adulthood (i.e., at ages 22–27 years, and mean age 24.7). Using baseline data in 1997, we defined indicators for self-reported gender and race (1 = non-Hispanic black, 0 = non-Hispanic white, excluding persons of mixed race), and also age in years. We defined early life SES (1 = low, 0 = high) according to the sample median split of the first principal component from several measures of family SES: maternal education, household income in US dollars (truncated), and parental net worth, all measured at baseline in 1997. We

assumed that this measure of SES in adolescence was a suitable proxy for SES in childhood. Unemployment was coded as a binary variable from current employment status in 2006, with individuals not in the labor market coded as missing. Incarceration was coded as a binary variable indicating self-reported residence in jail for any follow-up survey through 2006 or having been sentenced to a correctional institution before baseline. Hourly wage in 2006 US dollars was first calculated as a weighted average across all current jobs among the employed and unincarcerated in 2006 or 2007 (using the proportion of total hours/week per job as weights), excluding possibly implausible wages below $1 or above $115 per hour and then log-transformed. These represent outcomes in 2006 or 2007 at ages 22 through 27 and match those used in other literature [24].

Notation

For notation, we will use Y to refer to an outcome, A to refer to race (1 = black, 0 = white), and B to refer to SES at baseline (1 = low, 0 = high), and C to denote covariates age and gender. Table 1 presents the notation for average outcomes μ_{ab} for groups with a particular race $A = a$ and SES $B = b$, for a given age and gender C (i.e., $E[Y|A = a, B = b, c]$). For example, the average outcome for black men with high SES would be denoted as μ_{10}.

The joint disparity and excess intersectional disparity

A joint disparity

Suppose we are interested in describing the difference in unemployment between black men with low early life SES, μ_{11}, as compared to white men with high early life SES, μ_{00}. We refer to this descriptive measure,

$$\mu_{11} - \mu_{00}$$

as a "joint disparity", because it compares outcomes among the group at the nexus of two marginalized categories, i.e., black men with low early life SES, to a group that does not belong to either marginalized category, i.e., white men with high early life SES. This measure has intrinsic policy value because health interventions and initiatives sometimes aim to improve outcomes for multiply marginalized populations. As an additive measure, it describes absolute gains in the population outcome that would be achieved were the disparity removed.

Table 1 Average outcomes among groups defined by two dimensions (e.g., the mean of the outcome Y among groups defined by race A and SES B, among a given age group and gender C (e.g., $\mu_{ab} = E[Y|A = a, B = b, c]$)

	Childhood SES (B)	
	Low = 1	High = 0
Race (A)		
Black = 1	μ_{11}	μ_{10}
White = 0	μ_{01}	μ_{00}

Referent disparities and the excess intersectional disparity

Disparities for multiply marginalized populations can be further described by comparing the joint disparity to disparities among those who only belong to one marginalized population. The first of these disparity measures, $\mu_{01} - \mu_{00}$, compares outcomes for white men with low SES to white men with high SES. We refer to it as the referent SES disparity because it evaluates SES disparities among whites, the reference category used for race. It describes how outcomes are patterned by social disadvantage among those who do not encounter racism. The other disparity measure, $\mu_{10} - \mu_{00}$, compares outcomes for blacks with high SES to whites with high SES. We likewise refer to it as the referent race disparity because it evaluates racial disparities among those with high SES, the reference category used for SES. It describes how outcomes are patterned by race among those who do not encounter economic disadvantage apart from race. Now, let us consider the difference between the joint disparity and the sum of these two referent disparities:

$$(\mu_{11} - \mu_{00}) - ((\mu_{10} - \mu_{00}) + (\mu_{01} - \mu_{00})),$$

which simplifies to $\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00}$. This measure, which we refer to as the "excess intersectional disparity," quantifies the amount by which the joint disparity surpasses the sum of two referent disparities. When it is greater than zero, its magnitude reflects how the disparity for the dually marginalized population (blacks with low SES) exceeds what we would expect considering disparities of singly marginalized populations together (i.e., disparities for blacks with high SES plus disparities for whites with low SES). It captures how racism patterns outcomes differently for those with low vs. high SES and, simultaneously, how economic disadvantage patterns outcomes differently for blacks vs. whites.

Decomposition of the joint disparity into referent and excess intersectional disparities

By definition, the joint disparity for blacks with low SES $\mu_{11} - \mu_{00}$ will always equal the sum of the referent SES disparity $\mu_{01} - \mu_{00}$, the referent race disparity $\mu_{10} - \mu_{00}$, and the excess intersectional disparity [15, 25]:

$$\mu_{11} - \mu_{00} = (\mu_{01} - \mu_{00}) + (\mu_{10} - \mu_{00}) + (\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})$$

Each component can be directly compared to the joint disparity in the absolute sense, or as a proportion, i.e., $(\mu_{01} - \mu_{00})/(\mu_{11} - \mu_{00})$, $(\mu_{10} - \mu_{00})/(\mu_{11} - \mu_{00})$, and $(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/(\mu_{11} - \mu_{00})$. These proportions always sum to one regardless of each component's magnitude or sign:

$$100\% = (\mu_{01} - \mu_{00})/(\mu_{11} - \mu_{00}) + (\mu_{10} - \mu_{00})/(\mu_{11} - \mu_{00}) + (\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/(\mu_{11} - \mu_{00})$$

Because of this, the decomposition allows any component to reflect equal, better, or worse outcomes for the non-marginalized group (e.g., whites with high SES) when it is the case. In the following examples, we show how to interpret each component's meaning relative to the joint disparity. This decomposition of the joint disparity into referent disparities and an excess intersectional disparity does not ascribe the specific processes by which these patterns arise. We return to this point in the "Discussion".

The composition of joint disparities in unemployment, wages, and incarceration

In Table 2 we report the average age-adjusted outcomes for groups defined by race and childhood SES. The joint disparity, referent disparities, and excess intersectional disparities are presented in Table 3, along with the percent of the joint disparity attributable to each component. In the "Appendix" we outline the analytic methods used to obtain these estimates. Our analysis raises equity issues in the distribution of resources and opportunity by race and SES. We discuss these deeper issues in the Discussion and, for now, focus on demonstrating the decomposition and its interpretation.

Unemployment

The unemployment rate was 19.9 % for black men with low SES and 6.5 % for white men with high SES (Table 2). The joint disparity in unemployment is then 19.9 % minus 6.5 %, equaling 13.4 %. The referent race disparity comparing blacks with high SES to whites with high SES was 12.0 % minus 6.5 % equaling 5.5 %. The referent SES disparity comparing whites with low SES to whites with high SES was 8.8 % minus 6.5 % equaling 2.3 %. The excess intersectional disparity is the joint disparity 13.4 % minus the referent race disparity 5.5 %, minus the referent SES disparity 2.3 %, equaling 5.6 %. When using model-based adjustment for age (Table 3), the estimate of the joint disparity in unemployment is 13.4 % (95 % CI 9.7–17.2); the referent race disparity is 5.9 % (95 % CI 1.5–10.7) which represents 5.9/13.4 = 44 % of the joint disparity; the referent SES disparity is 2.4 % (95 % CI 0.3–4.6) which represents 2.4/13.4 = 18 % of the joint disparity; and the excess intersectional disparity is 5.1 % (95 % CI −0.1 to 10.7), representing 5.1/13.4 = 38 % of the joint disparity. Thus, of the 13.4 % difference in unemployment for black men with high SES vs. white men with low SES, nearly two-fifths was due to race alone (i.e., apart from SES), a fifth due to SES alone (i.e., apart from race), and nearly two-fifths of the disparity lie beyond what we might expect from considering both SES alone and race alone.

Wages

Adjusting for age (Table 3), the joint disparity in log hourly wage comparing black men with low SES to white men with high SES was −0.26 (95 % CI −0.21 to −0.32). The referent race disparity (i.e., among men with high SES) was −0.14 (95 % CI −0.06 to −0.21), representing 53 % of the joint disparity. The referent SES disparity (i.e., among white men) was −0.12 (95 % CI −0.08 to −0.17), representing 45 % of the joint disparity. The excess intersectional disparity equaled the joint disparity −0.26 minus the referent disparities −0.14 and −0.12, essentially zero, representing none of the joint disparity. Nearly half the joint disparity in log hourly wage was due to race alone (i.e., apart from SES) and the other due to SES alone (i.e., apart from race). The joint disparity does not lie beyond

Table 2 Average outcomes in 2006/2007 among the NLSY97 cohort (with standard errors) stratified by race and early life SES

	Black, low SES (μ_{11})	Black, high SES (μ_{10})	White, low SES (μ_{01})	White, high SES (μ_{00})
Unemployment, %	19.9 (1.7)	12.0 (2.1)	8.8 (0.84)	6.5 (0.67)
Hourly wage, log	2.67 (0.02)	2.81 (0.02)	2.82 (0.03)	2.95 (0.02)
Incarceration, %	18.8 (1.4)	10.6 (1.7)	13.1 (0.9)	6.2 (0.6)

NLSY97 race-SES strata sample sizes by outcome: unemployment $n_{11} = 547$, $n_{10} = 249$, $n_{01} = 1135$, $n_{00} = 1363$; hourly wage $n_{11} = 500$, $n_{10} = 244$, $n_{01} = 1138$, $n_{00} = 1397$; incarceration $n_{11} = 828$, $n_{10} = 341$, $n_{01} = 1558$, $n_{00} = 1872$

Sample sizes vary across outcomes due to missing data. For each outcome and each joint strata of race and SES, the age distributions were very similar with mean 24.7 and standard deviation of 1.5 (detail not shown)

Table 3 Joint disparity and component disparities (with standard errors) for average outcomes in 2006/2007 among the NLSY97 cohort

	Joint disparity ($\mu_{11} - \mu_{00}$)	Referent race/ethnicity disparity ($\mu_{10} - \mu_{00}$)	Referent SES disparity ($\mu_{01} - \mu_{00}$)	Excess intersectional disparity[a] $(\mu_{11} - \mu_{00}) - (\mu_{10} - \mu_{00}) - (\mu_{01} - \mu_{00})$
Unemployment, %				
Absolute difference	13.4 (1.9)	5.9 (2.3)	2.4 (1.1)	5.1 (2.9)
% Attributable		44 (17)	18 (8)	38 (21)
Hourly wage, log				
Absolute difference	−0.26 (.03)	−0.14 (0.04)	−0.12 (0.02)	0.00 (0.05)
% Attributable		53 (12)	45 (7)	1 (15)
Incarceration, %				
Absolute difference	11.3 (1.5)	3.3 (1.8)	6.4 (1.0)	1.6 (2.4)
% Attributable		35 (14)	55 (9)	11 (19)

[a] The excess intersectional disparity equals the joint disparity minus the referent race/ethnicity disparity minus the referent SES disparity

what we might expect from considering both SES alone and race alone.

Incarceration

Adjusting for age (Table 3), the joint disparity in incarceration was 11.3 % (95 % CI 8–14). The referent race disparity was 3.3 % (95 % CI −0.2 to 6.9), about 35 % of the joint disparity. The referent SES disparity was 6.4 % (95 % CI 4.4–8.5), or about 55 % of the joint disparity. The remainder, the excess intersectional disparity, was 1.6 % (95 % CI −3.1 to 6.3), representing 11 % of the joint disparity. Just over a third of the gap in incarceration rates between blacks with low SES and whites with high SES was due to race alone (i.e., apart from SES), and half due to SES alone (i.e., apart from race). Only eleven percent of the joint disparities lie beyond what we might expect from considering both SES alone and race alone.

Other measures of additive statistical interaction

We have demonstrated that the joint disparity measure provides a meaningful index for the well-being of multiply marginalized groups. Its components, the two referent disparities and the excess intersectional disparity, provide insight into which social statuses—race versus SES versus their intersection—are responsible for the joint disparity's magnitude. Other measures of additive statistical interaction have been proposed for studying intersectionality in public health, including the synergy index (SI), attributable proportion (AP), the relative excess risk for interaction (RERI), heterogeneity of effect measures [15], and the ratio of observed to expected joint effects (on the relative scale; RJE) [16]. Although, each of them is useful for detecting the presence of an excess intersectional disparity, some are better suited for understanding the absolute risk among multiply marginalized groups whereas as others provide insight into their excess risk, i.e., the joint disparity. Some do not focus attention on multiply marginalized groups at all but towards disparities along a primary axis. Here, we conceptually review each measure; we discuss estimation with additive and multiplicative regression models in the "Appendix".

The synergy index can be written as the ratio of the observed joint disparity to that which would be expected if there were no excess intersectional disparity (i.e., the sum of the referent race and referent race disparities):

$$\text{SI} = (\mu_{11} - \mu_{00})/((\mu_{10} - \mu_{00}) + (\mu_{01} - \mu_{00}))$$

In our unemployment example, the synergy index is 1.8 (95 % CI 0.9–4.0), suggesting that the intersection of race and SES is responsible for almost doubling the joint disparity in unemployment. This concise information is very useful for understanding intersectionality in unemployment but omits information on the absolute excess unemployment for black men with low SES.

Other measures of additive interaction focus our attention on the joint risk—the absolute risk or mean outcome among the multiply marginalized group—as opposed to the excess risk, i.e., the joint disparity. Considering the recently proposed ratio of observed versus expected joint effects on the relative scale (RJE). This measure can be expressed as follows:

$$\text{RJE} = \mu_{11}/(\mu_{10} + \mu_{01} - \mu_{00})$$

It compares the observed mean outcome in the multiply marginalized group vs. that which would be expected if race alone and/or SES alone were sufficient to explain the mean outcome. In our example, RJE = 1.4 (95 % CI 1.0–2.0), indicating that the unemployment rate for black men with low SES is 40 % higher than what we would expect if race alone and/or SES alone were sufficient to explain it.

The contribution of the excess intersectional disparity to the joint risk among blacks with low SES can be seen under the following decomposition [26]:

$$\mu_{11} = \mu_{00} + (\mu_{10} - \mu_{00}) + (\mu_{01} - \mu_{00}) + (\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})$$

The first term is equivalent to what the mean outcome among blacks with SES would be if there were no race or SES disparities, namely, the mean outcome among whites with high SES. The second and third terms are the referent race and referent SES disparities, and represent respectively, the independent contributions of race and SES. The last term is the excess intersectional disparity and when it is taken as a proportion of the mean outcome for blacks with low SES, we have what is called the attributable proportion (AP):

$$\text{AP} = (\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/\mu_{11}$$

In our example, AP = 25 % (95 % CI 4.1–50.0), indicating that a quarter of the unemployment rate among blacks with low SES (which was 19.9 %) can be explained by the intersection of race and SES.

Another widely used measure of additive interaction is the relative excess risk for interaction (RERI) which can be written as the excess intersectional disparity divided by the mean outcome among the non-marginalized:

$$\text{RERI} = (\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/\mu_{00}$$

In our example, the RERI is positive, 0.77 (95 % CI −0.12 to 1.68), indicating that the excess intersectional disparity is also positive and that race alone and SES alone are insufficient to explain the joint disparity. However, this value does not inform about the absolute or excess unemployment among blacks with high SES. While the RERI measure appears useful for investigating hypotheses about intersectionality, it appears less useful for tracking the health of multiply marginalized groups.

Many health researchers who examine the intersection of social factors do not use explicit measures of statistical interaction, but rather ask how disparities along one axis vary within levels of another. In our motivating example, this would be akin to comparing racial disparities in unemployment among those with low SES (the non-referent race disparity, $\mu_{11} - \mu_{10}$ 11.1 % (95 % CI 7.2–15.0)) to such disparities among those with high SES (to the referent race disparity, μ_{10}-μ_{00}, 5.9 % (95 % CI 1.7–10.5)). The difference between non-referent and referent race disparities equals the excess intersectional disparity, $(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00}) = (\mu_{11} - \mu_{01}) - (\mu_{10} - \mu_{00})$, 5.1 % (95 % CI −0.8 to 10.7). We see that the non-referent race disparity among those with low SES is greater than its corresponding referent disparity among those with high SES, so that the excess intersectional disparity positive. Race alone and socioeconomic status alone are insufficient to understand the joint disparity for blacks with low SES. Though this approach sheds light on the joint disparity, it can obscure understanding of its magnitude, as the referent and non-referent race disparities are in fact stratified measures that have adjusted away the effect of SES. More succinctly, readers will not know from the referent race disparity (5.5 %) and the non-referent race disparity (11.1 %) alone that black men with low SES have an excess 13.4 % unemployment than white men with high SES, nor that they were unemployed at a rate of 19.9 %.

Discussion

We have considered the joint disparity, a measure that describes health inequities for populations at the nexus of marginalized social statuses. The measure has intrinsic policy value because health interventions and initiatives sometimes aim to improve outcomes for multiply marginalized populations. For example, it could be used to set targets for population health. Its decomposition sheds light on the importance of each social status category and their intersection for shaping the joint disparity. Such quantitative evidence may help guide future research efforts and tailor interventions for specific outcomes. We have also considered alternative measures of additive interaction and showed that some provide insight into the joint disparity, whereas others are more relevant to the joint risk. In our example, both race and SES were critical in shaping each joint disparity but in different ways. For incarceration, SES was responsible for a majority of the disparity. For wages, each of race and SES was responsible for about half. For unemployment, race was more important than SES but there was also a strong intersectional component. Only for the disparity in unemployment was the intersectional component substantial in magnitude; there it accounted for about two-fifths of the disparity. However, even when the intersectional component is zero, one should not overlook the fact that the doubly marginalized group can still be greatly disadvantaged by both race and SES. The absence of an intersectional disparity only means that the joint disparity does not exceed the sum of two referent disparities, and this sum, as was the case for wages, can still be very substantial.

These striking patterns we observed may be illuminated by evidence from the social science literature. The large wage disparity for young black men with low childhood SES likely reflects gaps in educational quality due to residential segregation, lower educational attainment [27], and a higher proportion of black workers in low-skilled jobs (SES disparities). It also reflects the lower pay that blacks often receive at similar levels of education [8], more

frequent "channeling down" to lower status jobs [28], and harsher punishment in job evaluations which can derail career growth [29] (race disparities). The pattern of incarceration disparities reflects gaps in educational attainment, as rates are higher for those with no high school diploma [30]. Racial bias in the criminal justice system is also a major contributor: even though there are no racial differences in drug use, blacks are more likely than whites to be arrested, charged, sentenced, and incarcerated for drug-related crimes [31]. The higher unemployment rate may be explained by several factors. Studies have shown that employers carry negative stigma towards impoverished black male youth [32]. Others have documented higher callback rates for whites with criminal records than blacks without one, despite equivalent resumes [28, 33]. Meanwhile, blacks are incarcerated at the highest rate and many employers avoid hiring applicants with a criminal record. Even if these issues were absent, though, there are still fewer job prospects available for black men with limited education [22]. Many manufacturing and production jobs have disappeared as the US has moved towards an information and services-based economy. The large intersectional disparity we observed suggests that these reduced opportunities are stronger barriers for low SES black men than for their white counterparts.

More broadly, applications of intersectionality are emerging in the mental health services literature. One interesting example is from Hahm et al.'s analysis [34] of race/ethnicity and gender disparities across the spectrum of depression care, including receipt of screening, any mental health care, and also adequate mental healthcare as reflected in treatment guidelines. Focusing on additive measures, they estimated racial/ethnic disparities among women and men, gender disparities within racial/ethnic groups, and what they called a "differences-in-differences" estimator which is equivalent to an additive interaction (and also the excess intersectional disparity). Among other results, they reported lower screening and treatment rates for blacks among men and women but similar rates of adequate care among those treated. From the perspective of gender, there were lower rates of screening but no differences in treatment or adequacy for white men compared to white women; black men had slightly lower screening rates, higher rates of care, but similar adequacy as compared to black women. The interaction was only significant for screening such that gender disparities were greater among whites, and racial disparities were greater among women, by 4.2 % points which represents 69 % of the difference in screening rates between black men (52.7 %) and white women (58.6 %). These analyses suggest that considering how gender processes in mental health care differ by race (and vice versa) could be important for improving depression screening among black men, but perhaps less so for improving treatment initiation or adequacy. In other examples, authors have examined the intersection of race/ethnicity and mental health itself to understand disparities in chronic disease outcomes. One example includes Carliner et al.'s systematic review of racial differences in cardiovascular risk factors among those with and without serious mental illness [35]. A key issue in integrating mental and primary health care is how to tailor preventive medicine approaches for racial/ethnic minorities with schizophrenia and bipolar disorder.

Our proposal to focus on a joint disparity and its components naturally relates to many aspects of intersectionality. One of its main tenets is to raise awareness and give voice to groups whose needs might be overlooked when research, initiatives and policies focus on ameliorating disparities across one social category [5]. The joint disparity and its decomposition explicitly show how outcomes for multiply marginalized populations fare beyond those of singly or non-marginalized groups. This approach also makes explicit when and how multiple social categories are relevant. In our motivating example, both race and early life SES were related to larger disparities such that black men with low SES had far higher rates of unemployment, lower wages, and higher incarceration than any other group. But the intersection of race and SES was most important for disparities in unemployment. Such results suggest that processes underlying unemployment disparities differ across race and levels of SES. But in and of itself, our method does not explain how or why this is so. Furthermore, our proposal cannot replace the critical role of qualitative studies to uncover the unique experiences of multiply marginalized populations. A complementary approach could involve contemporary mediation analysis to understand how the joint disparity might change if disparities in its determinants were resolved, e.g., how joint unemployment disparities would change if black men with low SES had the same distribution of educational performance as white men with high SES [36]. Mediation analysis of disparities usually targets disparities along single axes. Another perspective of intersectionality examines interlocking systems of power as opposed to intersecting identities [9]. This might be captured by examining and decomposing joint disparities defined by membership based on "higher" level characteristics like, for example, group-based indicators of social status.

There are some issues and limitations that should be acknowledged. Many studies in the intersectionality literature are in fact motivated by trying to understand the intersection of three categories: race, class, and gender [5, 9]. Adapting these methods to incorporate more than two dimensions could be done in several ways and this should be explored in future research. But such approaches, like the ones presented here, may be challenging to

implement in studies powered to detect only marginal differences across a single social status. This issue will be exacerbated when statuses are highly correlated. Thus, research aims involving intersectionality should be considered at the design phase, where investigators can craft their sampling strategies to ensure adequate sample sizes. This approach still carries meaning in so-called "paradoxical" situations where the singly marginalized group fares worse than the multiply marginalized group (so that the excess intersectional disparity is negative), i.e., the intersection does not appear to be important for the joint disparity. Another issue is the use of binary variables to define social statuses. Some social dimensions involve more than two categories, and in fact some represent a gradient, e.g., SES. Our decision to dichotomize SES may have obscured important patterns. Incorporating multivalued statuses could be an important area of methods development for understanding joint disparities. Also, our weighted analysis of the NLSY97 data did not account for its sampling design or attrition, which was higher among blacks, those with lower family socioeconomic status, and was likely associated with wage, unemployment and incarceration outcomes [37]. Relatedly, the unemployment disparities do not apply to those who have not been actively seeking employment. The degree to which the empirical results are biased by these selective forces, as well as applications of methods to address them, can be explored in future work. Last, we should emphasize that we have taken a descriptive approach. However, the decomposition and the other measures of additive interaction are still applicable when the disparities are taken to represent causal effects of race and SES [25], when proper adjustment has been made for confounding variables (i.e., a focus on joint effects and causal interaction). Our terminology accommodates the conduct of disparity studies in various fields. For example, in health services research, covariate adjustment is often done to align disparity metrics with conceptual frameworks of justice (i.e., descriptive measurement) [38]. In epidemiology, it is done to ask how disparities might change upon intervention (i.e., causal inference) [36].

We have considered a measure to describe disparities for populations who are marginalized in multiple ways, and a method to understand how much each social category and their intersection contribute to the overall disparity for the multiply marginalized population. We have also contrasted this approach with complementary measures that shed further light on the joint disparity and the joint risk. Coupled with existing qualitative and quantitative tools, these methods should be useful for monitoring the status and determinants of health in multiply marginalized populations, who often carry the greatest burden of disease.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to report.

Appendix

Decomposing the joint disparity: estimation via regression models

The main text proposes a decomposition of a joint disparity into component disparities. Mathematically, it is equivalent to estimators for decomposing a joint effect of two exposures into main effects and their causal interaction, when the joint effect can be identified from observational data [25]. Because the joint disparity is a descriptive measure, the decomposition can be computed from observed data without assumptions. To help interpretation, though, it may be useful to adjust for variables that proceed both dimensions (e.g., confounding variables, such as age). To obtain adjusted joint disparity measures for continuous outcomes one can fit standard linear regression for the outcome Y (e.g., unemployment) among men:

$$E[Y|\text{Race}, \text{SES}, \text{Age}] = \alpha_0 + \alpha_1\text{Race} + \alpha_2\text{SES} + \alpha_3\text{Race} \times \text{SES} + \alpha_4\text{Age} \quad (1)$$

Where, conditional on age, $\alpha_1 + \alpha_2 + \alpha_3$ equals the joint disparity in unemployment $\mu_{11} - \mu_{00}$ comparing black men with low SES to white men with high SES; α_1 equals $\mu_{10} - \mu_{00}$ the racial disparity in unemployment among high SES persons, α_2 equals $\mu_{01} - \mu_{00}$. the SES disparity among whites; and α_3 equals the excess intersectional disparity $\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00}$. In our underlying model α_1 is the referent race disparity, α_2 is the referent SES disparity, α_3 is the excess intersectional disparity. These can be reported as proportions, in relation to the joint disparity, i.e., $\alpha_1/(\alpha_1 + \alpha_2 + \alpha_3)$, $\alpha_2/(\alpha_1 + \alpha_2 + \alpha_3)$, and $\alpha_3/(\alpha_1 + \alpha_2 + \alpha_3)$. Standard errors can be obtained for these measures and the corresponding proportions [25].

We argue that disparity measures on the additive scale will be much more useful for public health planning purposes because they can be used to describe absolute gains in population health were that disparity fully addressed. Sometimes it is difficult to estimate such measures for binary outcomes using additive regression models. But the joint disparity and also each component can be estimated

using a saturated weighted linear regression model, where the weights are the inverse probability of jointly belonging to particular race/ethnic and SES categories. To do this, one first estimates two logistic regression models, one predicting childhood SES group conditional on age alone, and the other predicting race conditional on childhood SES and age:

$$\text{Logit } P[\text{SES} = \text{ses}|\text{Age}] = \theta_0 + \theta_1 \text{Age} \quad (2)$$

$$\text{Logit } P[\text{Race} = \textit{race}|\text{SES}, \text{Age}] = \phi_0 + \phi_1 \text{SES} + \phi_2 \text{Age} \quad (3)$$

Taking the predicted values from these models, one then develops a stabilized weight *SW* for each person according to their race and SES group membership:

$$\text{SW} = \frac{P[\text{SES} = \textit{ses}]}{P[\text{SES} = \text{ses}|\text{Age}]} \times \frac{P[\text{Race} = \text{race}]}{P[\text{Race} = \text{race}\,|\text{SES}, \text{Age}]}$$

with these, one then fits a saturated weighted linear regression model for the outcome given race, SES, and their product:

$$E[Y|\text{Race},\ \text{SES},\ \text{Age}] = \eta_0 + \eta_1 \text{Race} + \eta_2 \text{SES} + \eta_3 \text{Race} \times \text{SES} \quad (4)$$

Here $\eta_1 + \eta_2 + \eta_3$ equals the joint disparity in unemployment $\mu_{11} - \mu_{00}$ comparing black men with low SES to white men with high SES; η_1 equals $\mu_{10} - \mu_{00}$ the racial disparity in unemployment among high SES persons, i.e., the referent race disparity; η_2 equals $\mu_{01} - \mu_{00}$. the SES disparity among whites, i.e., the referent SES disparity; and η_3 equals the excess intersectional disparity $\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00}$. The estimates obtained from this approach differ from the previous model-based estimates, in that they are with respect to the entire population and not just those who share the same age group. Robust standard errors can be obtained for statistical inference (we refer the reader elsewhere for details [39]).

Another option is to estimate the proportion of the joint disparity due to each component disparity via multiplicative regression models. For example, if the binary outcome Y (e.g., unemployment) were rare in each stratum one could fit the logistic regression model among men:

$$\text{Logit } P[Y|\text{Race},\ \text{SES},\ \text{Age}] = \beta_0 + \beta_1 \text{Race} + \beta_2 \text{SES} + \beta_3 \text{Race} \times \text{SES} + \beta_4 \text{Age} \quad (5)$$

where, conditional on age, $(\exp(\beta_1) - 1)/(\exp(\beta_1 + \beta_2 + \beta_3) - 1)$ equals $(\mu_{10} - \mu_{00})/(\mu_{11} - \mu_{00})$ the ratio of the referent race disparity to the joint disparity. The quantity $(\exp(\beta_2) - 1)/(\exp(\beta_1 + \beta_2 + \beta_3) - 1)$ equals $(\mu_{01} - \mu_{00})/(\mu_{11} - \mu_{00})$ the ratio of the referent SES disparity to the joint disparity. The quantity $(\exp(\beta_1 + \beta_2 + \beta_3) - \exp(\beta_1) - \exp(\beta_2) + 1)/(\exp(\beta_1 + \beta_2 + \beta_3) - 1)$ is equal to $(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/(\mu_{11} - \mu_{00})$ the ratio of the excess intersectional disparity to the joint disparity. When the outcome is not rare in one or more strata (i.e., >10 %) the model can be fit using a log-link, and standard errors for either model can be obtained using the multivariate delta method [40, 41] or the non-parametric bootstrap.

Estimating other measures of additive interaction

Each of the model-based strategies described in the previous section can be used to estimate other measures of additive interaction. Suppose, we fit a conditional linear regression model for unemployment given age (e.g., model 1). Using the parameters from this model, we could estimate the synergy index (SI) as $(\alpha_1 + \alpha_2 + \alpha_3)/(\alpha_1 + \alpha_2)$, the ratio of observed vs. expected joint effects on the relative scale (RJE) as $(\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3)/(\alpha_0 + \alpha_1 + \alpha_2)$, the attributable proportion (AP) as $\alpha_3/(\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3)$, and the relative excess risk due to interaction (RERI) as α_3/α_0. If, instead we fit a saturated marginal structural model (e.g., model 4), then the same expressions can be used (replacing α with η) but now the measures would pertain to the entire population as opposed to a particular age group. Last, suppose we fit a conditional logistic regression model given age (e.g., model 5). We could use the parameters of this model to estimate the SI as $(\exp(\beta_1 + \beta_2 + \beta_3) - 1)/((\exp(\beta_1) - 1) + (\exp(\beta_2) - 1))$, RJE as $(\exp(\beta_1 + \beta_2 + \beta_3))/(\exp(\beta_1) + \exp(\beta_2) - 1)$, AP as $(\exp(\beta_1 + \beta_2 + \beta_3) - \exp(\beta_1) - \exp(\beta_2) + 1)/\exp(\beta_1 + \beta_2 + \beta_3)$, and RERI as $(\exp(\beta_1 + \beta_2 + \beta_3) - \exp(\beta_1) - \exp(\beta_2) + 1)$. Standard errors can be obtained for these measures through the non-parametric bootstrap or multivariate delta method [25]. Table 4 summarizes these methods' merits and limitations for understanding multiply marginalized groups.

Statistical analyses for NLSY examples

We estimated age-standardized means jointly stratified by race and SES, and also age-standardized differences comparing each strata to white men with high SES using inverse probability weighting [39]. Robust standard errors for the differences were obtained using the sandwich variance estimator for generalized estimating equations. Standard errors for the decomposition method described in the main text were estimated using unweighted generalized linear models adjusted for age, with the identity link and multivariate delta method for log-wages, and logit link for unemployment and incarceration. When incarceration and

Table 4 Approaches for using additive interaction to understand multiply marginalized groups

Approach/measure	Expression	Interpretation	Focus	Conceptual limitations
Joint disparity[b]	$\mu_{11} - \mu_{00}$	Excess outcome among the multiply marginalized group, as compared to the non-marginalized	–	–
Excess intersectional disparity	$\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00}$	Amount by which the joint disparity exceeds the sum of the referent disparities[b]	–	–
Ratio of excess intersectional disparity to joint disparity	$(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/(\mu_{11} - \mu_{00})$	Proportion of joint disparity attributable to the intersection of race and SES	Contribution to joint disparity	–
Synergy index (SI)	$(\mu_{11} - \mu_{00})/((\mu_{10} - \mu_{00}) + (\mu_{01} - \mu_{00}))$	Ratio of observed joint disparity to the what one would expect the joint disparity to be if the excess intersectional disparity were zero	Change in joint disparity	–
Attributable proportion (ratio of excess intersectional disparity to joint risk[c])	$(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/\mu_{11}$	Proportion of the joint risk[d] attributable to the intersection of race and SES	Contribution to joint risk[d]	Interpretation does not relate to joint disparity
Ratio of observed to expected relative joint effects (RJE)	$\mu_{11}/(\mu_{10} + \mu_{01} - \mu_{00})$	Ratio of the observed joint risk[d] to what one would expect the joint risk[d] to be if the excess intersectional disparity were zero	Change in joint risk[d]	Interpretation does not relate to joint disparity
Relative excess risk due to interaction	$(\mu_{11} - \mu_{10} - \mu_{01} + \mu_{00})/\mu_{00}$	The excess intersectional disparity scaled by the non-marginalized outcome	Presence of excess intersectional disparity	Interpretation does not relate to either joint disparity or joint risk[d]
Heterogeneity of effects	$\mu_{10} - \mu_{00}$ and $\mu_{11} - \mu_{01}$	The disparity for one category (race) within levels of another (SES)	Stratum-specific disparities, and presence of excess intersectional disparity	Adjusts away contribution of second status

[a] Mean outcome μ among blacks with low SES (μ_{11}), blacks with high SES (μ_{10}), whites with low SES (μ_{01}), whites with high SES (μ_{00})

[b] A referent disparity is the disparity for one social category at the reference level of the other category. For example, the race disparity among those with high SES (referent race disparity), or the SES disparity among whites (referent SES disparity)

[c] The joint disparity decomposes into the sum of the excess intersectional disparity and the referent disparities

[d] Joint risk = μ_{11}

unemployment rates were over 10 % for any stratum, we instead used the log-link and calculated standard errors using the non-parametric bootstrap with 5000 samples.

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