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Racial/Ethnic Discrimination and Cardiometabolic Diseases: A Systematic Review

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Abstract

Introduction Racial discrimination has been identified as a risk factor for cardiometabolic diseases, the leading cause of morbidity and mortality among racial/ethnic minority groups; however, there is no synthesis of current knowledge on the association between discrimination and cardiometabolic diseases. The objective of this systematic review was to summarize evidence linking racial/ethnic discrimination and cardiometabolic diseases.

Methods The review was conducted based on studies identified via electronic searches of 5 databases (PubMed, Google Scholar, WorldWideScience.org, ResearchGate and Microsoft Academic) using terms related to discrimination and cardiometabolic disease.

Results Of the 123 eligible studies included in the review, 87 were cross-sectional, 25 longitudinal, 8 quasi-experimental, 2 randomized controlled trials and 1 case–control. Cardiometabolic disease outcomes discussed were hypertension ($n=46$), cardiovascular disease ($n=40$), obesity ($n=12$), diabetes ($n=11$), metabolic syndrome ($n=9$), and chronic kidney disease ($n=5$). Although a variety of discrimination measures was employed across the studies, the Everyday Discrimination Scale was used most often (32.5%). African Americans/Blacks were the most frequently studied racial/ethnic group (53.1%), and American Indians the least (0.02%). Significant associations between racial/ethnic discrimination and cardiometabolic disease were found in 73.2% of the studies.

Discussion Racial/ethnic discrimination is positively associated with increased risk of cardiometabolic disease and higher levels of cardiometabolic biomarkers. Identifying racial/ethnic discrimination as a potential key contributor to the health inequities associated with cardiometabolic diseases is important for addressing the significant burden borne by racial/ethnic minorities.

Keywords Cardiometabolic disease · Racial/ethnic discrimination · Biomarkers · Racism · Health inequities

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Introduction

Cardiometabolic disorders (CMD) that affect cardiovascular and metabolic functions are the leading cause of morbidity and mortality worldwide [1]. The range of such CMD extends from cardiovascular diseases (CVD; such as hypertension, stroke, and coronary artery disease) to diabetes mellitus (type 2 diabetes), obesity, chronic kidney disease, and non-alcoholic fatty liver disease. Notably, CMD exacerbates the mortality risk from emerging illnesses, such as COVID-19 [2]. Prevention of this set of diseases could therefore significantly lessen disease burden and mortality risk across the world. Although many biological risk factors for CMD have been identified, recent work has shown that a large proportion of such disease could be attributed to environmental factors, influenced by social networks and socioeconomic status [3]. In addition, demographic analyses of CMD prevalence show marked disparities, with significant differences in incidence and outcomes, among racial/ethnic minority groups [4–7]. For example, in the United States, African Americans are approximately twice as likely to develop CMD and die from CMD complications in comparison with Whites [8]. African Americans also are twice as likely to have hypertension [9], Type 2 Diabetes (T2D) [10], and CVD [11]. Similarly, other racial/ethnic minority groups are disproportionately affected by CMD. Higher rates of CVD and T2D have been reported in Hispanic/Latino [12] communities, and South Asian ancestry has been found to be associated with a higher risk for CVD-related mortality [13]. Given the high rates of CMD-related mortality and morbidity among racial/ethnic minorities, identifying key factors contributing to these health inequities, such as racial/ethnic discrimination, is critical for supporting, enhancing, and developing effective prevention strategies.

The multifactorial nature of CMD suggests that, in addition to weak genetic influences, an array of environmental factors, such as features of the social environment, diet, lifestyle, and socioeconomic status, may be important determinants of disease risk [14]. Although several individual risk and lifestyle factors have been identified as key drivers of CMD risk, structural and interpersonal circumstances also can influence CMD risk, and predispose racial/ethnic minority groups to adverse CMD outcomes [11, 15]. Although such psychosocial and structural health barriers may be linked to racism and racial/ethnic discrimination [5, 16], neither their contribution nor the underlying mechanisms are well understood.

Previous work has shown that racism, structural and systemic practices that assign value to people based on the color of their skin [17], and racial discrimination, unfair treatment on the basis of skin color or perceived membership in a racial group [18], are critical determinants of health outcomes [17–19]. Experiences with racism and racial discrimination can be stress-inducing [20], which could have negative implications for cardiometabolic health among racial/ethnic minorities [21–23]. Psychosocial stress due to racial discrimination has been hypothesized to contribute to disparities in CMD incidence among racial/ethnic minority groups [4, 5], and several physiological mechanisms underlying the association between racial/ethnic discrimination and CMD have been proposed. These include discrimination stress-induced activation of the autonomic nervous system triggering the release of cortisol and catecholamines, resulting in increased blood pressure and cardiovascular reactivity [24, 25]. Also, chronic stress due to discrimination can increase inflammation [26] and allostatic load, resulting in wear and tear on bodily systems increasing the risks of CMD [27]. However, the roles and contributions of these factors are not well understood, and further work is required to gauge the full impact of discrimination on physiology, hemodynamics, and metabolism.

Such assessments of risk would be greatly facilitated by the identification of specific biomarkers that would be useful not only in identifying the physiologic contribution of discrimination exposure but also for developing more targeted approaches in primary and secondary CMD prevention [28]. Elucidation of such biomarkers could also aid in the identification of high-risk individuals, accurate diagnoses and prognosis of CMD, and monitoring the burden of disease [28, 29]. Therefore, identifying CMD biomarkers sensitive to discrimination exposure has utility in increasing knowledge and in potentially improving the disproportionate burden of CMD borne by racial/ethnic minorities.

To delineate the contribution of discrimination to CMD risk and to identify informative biomarkers, it is critically important to evaluate the association between racial/ethnic discrimination and CMD. Systematic reviews of the association between perceived racial/ethnic discrimination and increased CVD risk [30] and hypertension [24, 31] have been previously conducted. However, the association of racial/ethnic discrimination with cardiovascular and metabolic disease has not been examined. Because the two diseases share common etiology ("shared soil" hypothesis), looking at them collectively is important as it may provide a more comprehensive assessment of the impact of discrimination than by examining either disease alone. Therefore, the aim of this systematic review is twofold: 1) to examine what is known about the association between racial/ethnic discrimination and CMD among minority groups, and 2) to characterize CMD biomarkers sensitive to discrimination exposure.

Methods

Search Strategy

A comprehensive review of online databases was conducted in January 2021 and again in February 2023. This review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [32]. First, articles were identified using Boolean searches in five databases: PubMed, Google Scholar, WorldWideScience.org, ResearchGate, and Microsoft Academic. The search terms were "discrimination OR racism OR race-related stress AND cardiometabolic disease OR cardiovascular disease OR hypertension OR diabetes OR obesity OR chronic kidney disease OR coronary artery calcification". Additionally, manual searches of reference lists of articles identified were performed.

Eligibility Criteria

We included articles that met the following inclusion criteria: (1) participants with diagnosed or self-reported cardiometabolic diseases, (2) published in English in a peer-reviewed journal, (3) included racial/ethnic minorities, (4) examined racial/ethnic discrimination/racism, and (5) conducted in the United States. Because the experience of racial/ethnic discrimination differs across nations and cultures, we restricted inclusion to studies conducted in the U.S.

Data Extraction

The search process identified 1,773 records, and reference cross-checks produced an additional 3 records for a total of 1,776 articles. Elimination of duplicates ($n=951$) and articles with titles or abstracts irrelevant to the review (i.e., title and abstract did not include reference to discrimination and CMD, $n=656$) resulted in 169 articles. Of these articles, 46 were excluded after failing to meet eligibility criteria (i.e., no CMD outcome, $n=14$; racial/ethnic discrimination not assessed, $n=26$; conducted outside the U.S., $n=6$), yielding 123 eligible studies (Fig. 1).

Results

Study Characteristics

The descriptive characteristics (study design, sample size, biomarkers, discrimination measure used, and associations found) of studies included are detailed in Table 1. Data from 343,268 participants were included in the systematic review, with sample sizes ranging from 32 to 45,781 participants. Eighty-seven of the studies were cross-sectional, 25 were longitudinal, 8 were quasi-experimental, 2 were randomized controlled trials and 1 was a case–control. The most commonly used discrimination measures were the Everyday Discrimination Scale ($n=40$), Experiences of Discrimination Scale ($n=22$), Perceived Racism Scale ($n=10$), and Perceived Ethnic Discrimination Questionnaire ($n=11$) (Supplemental Table 1).

Discrimination and CMD Outcomes

Across these articles, African Americans/Blacks were the most often studied racial/ethnic group (53.1%), followed by Whites (33.5%), Hispanics/Latinos (9.3%), Asians (2.9%), Other (0.98%), Native Hawaiians/Pacific Islanders (0.2%) and American Indians (0.02%). Of the studies, 81 (65.8%) examined African Americans/Blacks, 29 (23.6%) examined African Americans/Blacks and Other races/ethnicities, and 13 (10.6%) examined other races/ethnicities only. Table 2 provides an overview of the CMDs and biomarkers examined. The most frequently examined CMDs were hypertension ($n=46$) and CVD ($n=40$). Other CMDs examined were diabetes ($n=11$), obesity ($n=12$), metabolic syndrome ($n=9$), and chronic kidney disease ($n=5$).

Of the studies, 73.2% ($n=90$) found that racial/ethnic discrimination was positively associated with a significant increase in CMD risk incidence (Table 1) [33–122]. Of the 87 studies using a cross-sectional design, 70.1% ($n=61$) found a significant positive association with CMD. For example, Cardarelli et al. evaluated 510 adults from the North Texas Healthy Heart Study [42]. Participants who experienced racial discrimination and passively responded to unfair treatment were 3 times more likely to have coronary artery calcification (CAC) compared to those who did not report any experiences of racial discrimination [42].

Twenty-five studies employed a longitudinal design, with 76% finding a positive association. For example, Forde et al. conducted a longitudinal cohort study of 1,845 African American adults participating in the Jackson Heart Study [56] and found that lifetime experience with discrimination was associated with a higher incidence of hypertension [56]. Also, 7 of 8 (87.5%) quasi-experimental studies found a positive association between experiences of racial/ethnic discrimination and CMD. In addition, Tull et al. employed a case control design [99] and Merritt et al. and Arriola et al. utilized a randomized controlled trial [80, 110], with all finding a significant positive association between racial/ethnic discrimination and CMD. However, 33 (26.8%) articles found no significant association between experiences of racial/ethnic discrimination and CMD [123–155]. Hypertension ($n=16$) was the most frequent CMD found to have no significant association with racial/ethnic discrimination,

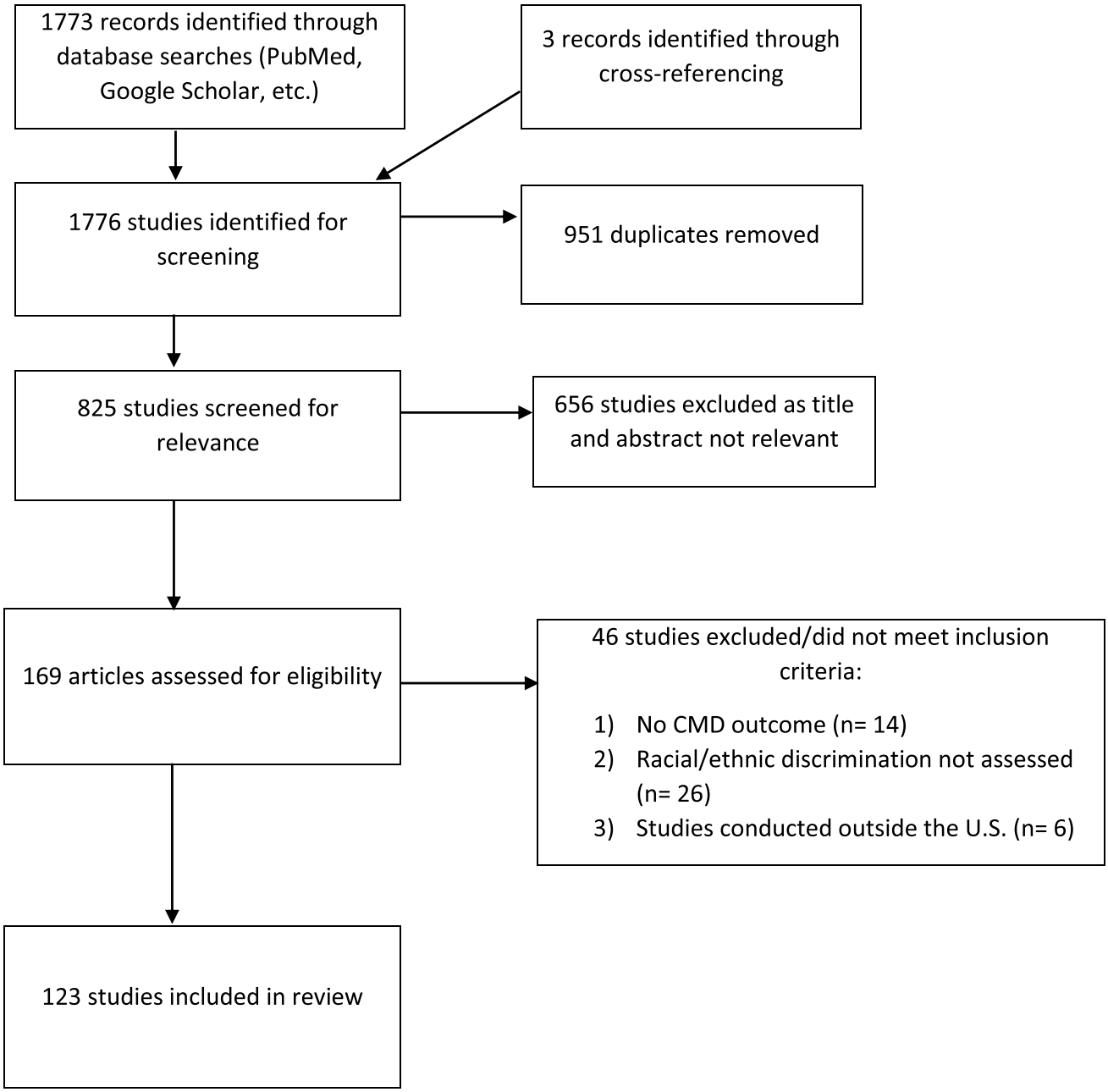

Fig. 1 Flow chart of article selection process

while CVD ($n=34$) was the most frequent outcome positively associated with racial/ethnic discrimination. In the 33 articles that found no significant association between experiences of racial/ethnic discrimination and CMD [123–155], the total population ($N=60{,}422$) was comprised of 49.5% African Americans, 33.3% Whites, and 17.2% Other races/ethnicities. The total population included adults aged 18–95 with a sample size range of 62–10,973 participants. SBP and DBP ($n=16$) were the most frequent biomarkers examined, and the Everyday Discrimination Scale ($n=13$) was the most frequently used discrimination measurement tool. In comparison, the 90 articles in which a significant association was found included a total population of 282,846 partipants, with sample size ranges of 32–45,781 participants. Most participants in these studies were African American adults, particularly African American women (56.4%), aged 18–95 [33–122].

Racial/Ethnic Discrimination and Biomarkers of CMD

Across the studies, a variety of CMD biomarkers were examined. Systolic blood pressure (SBP) and diastolic blood

Table 1 Characteristics of studies included

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
1	Troxel et al. 2003	Cross-sectional	*N* = 334 women aged 42–52, AA (*n* = 109) and White (*n* = 225)	Carotid artery Intima Media thickness	CVD	Everyday Discrimination Scale	Yes
2	Lewis et al. 2006	Cross-sectional	*N* = 181 AA women, aged 42–52	CAC	CVD	Everyday Discrimination Scale	Yes
3	Albert et al. 2008	Cross-sectional	*N* = 1,475 (790 Black, 494 White and 191 Hispanic)	CRP, CAC, IL-18 and MCP	CVD	Self-reported measure	No
4	Cooper et al. 2009	Cross-sectional	*N* = 116 adults, Black (*n* = 51), White (*n* = 65), women (*n* = 59, men (*n* = 57)	Plasma endothelin 1, MAP	CVD	The Scale of Ethnic Experience, Perceived Discrimination Sub-scale	Yes
5	Lewis et al. 2010	Cross-sectional	*N* = 296 older AA adults, women (71%), men (29%), mean age 73.1	CRP	CVD	Everyday Discrimination Scale	Yes
6	Mwendwa et al. 2011	Cross-sectional	*N* = 122 AA adults, aged 21–73, 53% women, 47% men, mean age 43.6	HDL, LDL and Triglycerides	CVD	Perceived Racism Scale	Yes
7	Cardarelli et al. 2010	Cross-sectional	*N* = 510, Hispanic (*n* = 193), AA (*n* = 167), White (*n* = 142)	CAC, HR, FBG	CVD	Experience of Discrimination Scale	Yes
8	Ayotte et al. 2012	Cross-sectional	*N* = 793 adult male veterans aged 31–85, White (*n* = 629), Black (*n* = 164), mean age 61.9	Self-report	CVD	Krieger Racial Discrimination Questionnaire	Yes
9	Chae et al. 2012	Cross-sectional	*N* = 5,022 Black American adults	Self-reported measure	CVD	Major Experiences of Discrimination	Yes
10	Szanton et al. 2012	Cross-sectional	*N* = 629 adults, Black (*n* = 308), White (*n* = 321), men (47%), women (53%)	RBC heme degradation	CVD	Self-reported measure	Yes
11	Wagner et al. 2013	Cross-sectional	*N* = 32 adult women, Black (*n* = 16) and White (*n* = 16) with type 2 diabetes	HR variability, norepinephrine, and cortisol	CVD	Schedule of Racist events Scale	Yes
12	Goosby et al. 2015	Cross-sectional	*N* = 49 AA low-income youth aged 10–15, 79% women and 21% men	CRP, SBP and DBP	CVD	Everyday Discrimination Scale adapted	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
13	Giurgescu et al. 2016	Cross-sectional	*N* = 96 pregnant AA women, aged 18–41, gestational age range of 15–26 weeks	IL1, IL2, IL 4, IL 6, IL10	Systemic inflammation, CVD	Experiences of Discrimination Scale	Yes
14	Mouzon et al. 2016	Cross-sectional	*N* = 3,570 AA adults, 44% men, 56% women	Self-reported CV health	CVD	Everyday Discrimination Scale	Yes
15	Nadimpalli et al. 2016	Cross-sectional	*N* = 757 Asian Indian, men (*n* = 408), women (*n* = 349), aged 40–83	Cardiovascular risk scale (CRS), BMI, BP and FBG	CVD	Everyday Discrimination Scale	No
16	Hill et al. 2017	Cross-sectional	*N* = 99 AA college students, women (58%), men (42%), mean age 19.9	Heart Rate Variability (HRV)	CVD	Perceived Ethnic Discrimination Questionnaire	Yes
17	Williams et al. 2017	Cross-sectional	*N* = 101 college-age students, AA (*n* = 45), White (*n* = 56)	Heart Rate Variability (HRV)	CVD	Perceived Ethnic Discrimination Questionnaire	Yes
18	Hill et al. 2018	Cross-sectional	*N* = 57 AA adults, 51% women, 49% men, mean age 33	α1 and þ adrenergic receptors	CVD	Perceived Racism Scale	Yes
19	Lewis et al. 2019	Cross-sectional	*N* = 52 AA women aged 30–50 years, mean age 40.8	Carotid Intima-media thickness (IMT), SBP, DBP	CVD	Race-Based Rejection Sensitivity Questionnaire, Schedule of Racist Events	Yes
20	Lu et al. 2019	Cross-sectional	*N* = 997 AA women, aged 40–70	Leukocyte telomere length	CVD	Everyday Discrimination Scale	Yes
21	Drolet and Lucas 2020	Cross-sectional	*N* = 118 AA adults, men (*n* = 36), women (*n* = 82) aged 18–63	CRP	CVD	Racism and Life Experiences Scale	Yes
22	Turkson-Ocran 2020	Cross-sectional	*N* = 342 African immigrant adults, men (*n* = 134), women (*n* = 208), mean age 47	SBP, DBP, BMI, self-report diabetes	CVD	Everyday Discrimination Scale	Yes
23	Cuevas et al. 2021	Cross-sectional	*N* = 1,106 adults, White (*n* = 520), Black (*n* = 586), men (*n* = 413), women (*n* = 693), median age 40	Self-report	CVD	Self-report	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
24	Kreiger and Sidney 1996	Cross-sectional	*N* = 4,086 adults, Black (*n* = 1,974), White (*n* = 2,112) men (*n* = 1,837), women (*n* = 2,249)	SBP and DBP	HTN	Experiences of Discrimination Scale	Yes
25	Clark 2000	Cross-sectional	*N* = 39, AA graduate and undergraduate women (aged 18–33)	SBP and DBP vascular reactivity	HTN	Perceived Racism Scale	Yes
26	Steffen et al. 2003	Cross-sectional	*N* = 69 AA adults, men (*n* = 30) and women (*n* = 39), aged 25–44	SBP and DBP	HTN	Perceived Racism Scale	Yes
27	Din-Dzethiam et al. 2004	Cross-sectional	*N* = 356 adults, AA men (*n* = 160) and women (*n* = 196)	SBP and DBP	HTN	Self-reported measure	Yes
28	Peters 2004	Cross-sectional	*N* = 162 AA adults, men (*n* = 29), women (*n* = 133), aged 18–80	SBP and DBP	HTN	Racism and Life Experiences Scale (RaLES) and Krieger Racial Discrimination Questionnaire (KRDQ)	No
29	Davis et al. 2005	Cross-sectional	*N* = 356 AA adults, men (*n* = 160), women (*n* = 196)	SBP and DBP	HTN	Adaptation of Perceived Racism Scale and Index of Race-Related Stress	No
30	Matthews et al. 2005	Cross-sectional	*N* = 212 adolescents, Black (*n* = 106), White (*n* = 106), men (*n* = 105), women (*n* = 107)	ABP and Heart Rate	HTN	Everyday Discrimination Scale	No
31	Brown et al. 2006	Cross-sectional	*N* = 3,300 [AA (*n* = 934), Caucasian (*n* = 1,549), Chinese (*n* = 250), Hispanic (*n* = 286), and Japanese (*n* = 281) women]	SBP and DBP	HTN	Everyday Discrimination Scale	No
32	Peters 2006	Cross-sectional	*N* = 162 AA adults, men (*n* = 29), women (*n* = 133), aged 18–80	SBP and DBP	HTN	Racism and Life Experiences Scale (RaLES) and Krieger Racial Discrimination Questionnaire (KRDQ)	No

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
33	Ryan et al. 2006	Cross-sectional	$N=666$ adults, AA ($n=78$), Black immigrants ($n=112$), Latino immigrants ($n=476$)	SBP and DBP	HTN	The Reactions to Race Module	Yes
34	Hill et al. 2007	Cross-sectional	$N=40$ AA college students, men ($n=19$) women ($n=21$)	ABP monitor for SBP and DBP	HTN	Perceived Racism Scale	Yes, for DBP only
35	Pointer et al. 2008	Cross-sectional	$N=176$ AA adults, men ($n=63$), women ($n=113$), aged 18–65	SBP, DBP, MAP and HR	HTN	Perceived Racism Scale	No
36	Roberts et al. 2008	Cross-sectional	$N=1,110$ AA adults, men ($n=393$) and women ($n=717$), aged 25–50	SBP and DBP	HTN	Everyday Discrimination Scale	Yes, AA women only
37	Salomon and Jagusztyn 2008	Cross-sectional	$N=70$ college undergraduates, White ($n=28$), Black ($n=24$), and Latino ($n=18$), men ($n=20$) and women ($n=50$)	SBP, DBP and HR reactivity	HTN	Perceived Ethnic Discrimination Questionnaire	Yes
38	Singleton et al. 2008	Cross-sectional	$N=52$ Black adults, men ($n=11$) and women ($n=41$), aged 20–64	ABP monitor for SBP and DBP	HTN	Perceived Racism scale (PRS)	Yes
39	Victor et al. 2008	Cross-sectional	$N=1,514$ adults, Black ($n=1,194$), White ($n=320$) hypertensive subjects aged 18–64	ABP monitor for SBP and DBP	HTN control	Kaiser Family Foundation Survey of Race, Ethnicity and Medical Care	No
40	Barksdale et al. 2009	Cross-sectional	$N=211$ [Black American women ($n=147$), men ($n=64$)]	Mean SBP and DBP	HTN	Perceived Racism Scale	No
41	Lewis et al. 2009	Cross-sectional	$N=4,694$, AA ($n=2,826$), White ($n=1,868$), women (60%), men (40%)	SBP, DBP	HTN	Everyday Discrimination Scale	Yes, DBP only
42	McClure et al. 2010	Cross-sectional	$N=132$ Latin American adults, men ($n=46$), women ($n=86$)	SBP and DBP	HTN	Perceived Discrimination Scale	Yes
43	Smart Richman et al. 2010	Cross-sectional	$N=62$ adults, Black ($n=31$) and White ($n=31$), aged 18–53	ABP monitor for SBP and DBP	Nocturnal dipping/ HTN	Everyday Discrimination Scale	No

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
44	Krieger et al. 2010	Cross-sectional	*N* = 1,460 adults, US-born Black (*n* = 442) and White (*n* = 1018)	Self-reported HTN	HTN	Experiences of Discrimination Scale	No
45	Mujahid et al. 2011	Cross-sectional	*N* = 2,679 adults, AA (*n* = 1,159), Hispanic (*n* = 415), White (*n* = 1,105) men (*n* = 1,236) and women (*n* = 1,443)	SBP and DBP	HTN	Major Experiences of Discrimination Scale and Everyday Discrimination Scale	Yes
46	Kaholokula et al. 2012	Cross-sectional	*N* = 146 Native Hawaiian adults, men (*n* = 42), women (*n* = 104)	SBP, DBP, Salivary Cortisol	HTN	Oppression Questionnaire	Yes
47	Klimentidis et al. 2012	Cross-sectional	*N* = 294 children aged 7–12, AA (*n* = 96), EA (*n* = 114), Hispanic American (*n* = 78), biracial (*n* = 6), men (53%), women (47%)	SBP and DBP	HTN	Everyday Discrimination Scale	Yes
48	Neblett and Carter 2012	Cross-sectional	*N* = 210 AA young adults, men (*n* = 60), women (*n* = 150), mean age 20.2	SBP, DBP, MAP	HTN	Racism and Life Experiences Scale (RaLES)	No
49	Sims et al. 2012	Cross-sectional	*N* = 4,939 AA, aged 35–84, women (*n* = 3,123), men (*n* = 1816)	SBP and DBP	HTN	Jackson Heart Study Discrimination Instrument	Yes
50	Gregoski et al. 2013	Cross-sectional	*N* = 352 young adults, AA (*n* = 175), White (*n* = 177)	Plasma endothelin 1, ABP	Nocturnal dipping/ HTN	Everyday Discrimination Scale	Yes
51	Kreiger et al. 2013	Cross-sectional	*N* = 1,005 adults, Black (*n* = 504), White (*n* = 501), men (*n* = 340, women (*n* = 665)	SBP, DBP, Self-report CVD	HTN, CVD	Implicit Association Test, Experiences of Discrimination Scale, Everyday Discrimination Scale	No
52	Wagner et al. 2015	Cross-sectional	*N* = 77 adult women, Black (*n* = 39), White (*n* = 38), mean age 56	ABP monitor for SBP and DBP	HTN	Everyday Discrimination Scale	Yes
53	Beaty-Moody et al. 2016	Cross-sectional	*N* = 607, Black (*n* = 318) and Latino(a) (*n* = 289)	ABP monitor for SBP and DBP	HTN	Perceived Ethnic Discrimination Questionnaire	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
54	Rodriguez et al. 2016	Cross-sectional	$N=180$ Hispanic adults, Hispanic Black (34.4%), Hispanic White (41.1%) and Other (24.5%)	ABP monitor for SBP and DBP	Nocturnal dipping/ HTN	Perceived Ethnic Discrimination Questionnaire	Yes
55	Orom et al. 2017	Cross-sectional	$N=1,533$ men with prostate cancer, Black ($n=190$), White ($n=1,193$), Hispanic ($n=120$), other ($n=30$)	Self-reported HTN	HTN	Experiences of Discrimination Scale	Yes
56	Taylor et al. 2017	Cross-sectional	$N=2,932$ AA adults, women (72%), men (38%), aged 21–85	SLC4A5 gene	HTN	Jackson Heart Study Discrimination Instrument	Yes
57	Thayer et al. 2017	Cross-sectional	$N=77$ American Indians, men ($n=21$) and women ($n=56$)	SBP and DBP	HTN	Everyday Discrimination Scale	Yes
58	Lebron et al. 2018	Cross-sectional	$N=219$ adults, Latino ($n=59$), Black ($n=107$), White ($n=47$)	SBP, DBP	HTN	Everyday Unfair Treatment Scale and Acute Unfair Treatment Index	Yes
59	Ing et al. 2019	Cross-sectional	$N=171$ Native Hawaiian adults, women (71%), men (29%), mean age 57	Self-reported HTN	HTN	Everyday Discrimination Scale	Yes
60	Michaels et al. 2019	Cross-sectional	$N=208$ AA women aged 30–50, mean age 42	SBP, DBP	HTN	Everyday Discrimination Scale	No
61	Gabriel et al. 2020	Cross-sectional	$N=1360$ adults, Black ($n=804$), White ($n=556$)	SBP and DBP	HTN	Experiences of Discrimination Scale	No
62	Wright et al. 2020	Cross-sectional	$N=226$ AA women, mean age 31.2	SBP and DBP	HTN	Experiences of Discrimination Scale and the Race Related Events Scale	No
63	Wagner et al. 2013	Cross-sectional	$N=77$ adult women, Black ($n=39$), White ($n=38$), mean age 56	FBG, Fasting Insulin, HbA1C	Type 2 Diabetes	Experiences of Discrimination Scale	Yes, for Insulin Resistance
64	Dawson et al. 2015	Cross-sectional	$N=602$, AA (64.9%), White (35.1%), women (38.4%) and men (61.6%)	HbA1c, SBP, DBP and LDL	Type 2 Diabetes and HTN	DISTANCE survey	Yes, for HTN

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
65	Reynolds et al. 2015	Cross-sectional	$N=602$ adults, AA ($n=399$), Other ($n=203$), men ($n=369$) and women ($n=233$)	HbA1c	Type 2 Diabetes	DISTANCE survey	No
66	MacGregor et al. 2020	Cross-sectional	$N=595$ women, White ($n=368$), Black ($n=99$), Hispanic ($n=93$), Other ($n=35$)	1 h. glucose challenge test, 3 h glucose tolerance test	Gestational Diabetes	Everyday Discrimination Scale	No
67	Kamody et al. 2021	Cross-sectional	$N=6223$ Hispanic adults	Self-report, BMI	Diabetes	Experiences of Discrimination Scale	Yes
68	Erbetta et al. 2022	Cross-sectional	$N=4084$ women, US-born (47.6%), Foreign-born (52.4%), White ($n=1,191$), Black ($n=861$), Hispanic ($n=1,329$), Other ($n=703$)	Self-report	Gestational diabetes	Self-report	Yes
69	Gee et al. 2008	Cross-sectional	$N=1956$ Asian Americans, men ($n=931$), women ($n=1025$), mean age 41.1	BMI	Obesity	Everyday Discrimination Scale	Yes
70	Hunte and Williams 2009	Cross-sectional	$N=3025$ adults, NH White ($n=1206$), NH Black ($n=1008$), Hispanic ($n=811$), mean age 42.6	BMI, Waist circumference	Obesity	Everyday Discrimination Scale	No
71	Mwendwa et al. 2011	Cross-sectional	$N=110$ AA women, mean age 47	BMI	Obesity	Perceived Racism Scale	Yes
72	Johnson et al. 2012	Cross-sectional	$N=350$ AA women aged 18–71, mean BMI: 34.8	BMI	Obesity	Perceived Discrimination Questionnaire	No
73	Mccubin and Antonio 2012	Cross-sectional	$N=367$ Native Hawaiian, men ($n=118$), women ($n=249$)	BMI	Obesity	Everyday Discrimination Scale	Yes
74	Stepanikova et al. 2017	Cross-sectional	$N=5,301$ AA adults, men (36.5%), women (64.5%), aged 21–95	BMI, Waist circumference	Obesity	Jackson Heart Study Discrimination Instrument	No
75	Thorpe et al. 2017	Cross-sectional	$N=1,209$ AA men, aged 18 and older, mean age 42	BMI	Obesity	Everyday Discrimination Scale and Major Experiences of discrimination Scale	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
76	Cuevas et al. 2019	Cross-sectional	$N=32,747$ adults, 47.92% men, 52.08% women, mean age 45.08	BMI	Obesity	Experiences of Discrimination Scale	Yes
77	Longmire-Avital and McQueen 2019	Cross-sectional	$N=149$ collegiate Black American women aged 18–25	BMI	Obesity	Index of Race-Related Stress	Yes
78	Hagiwara et al. 2021	Cross-sectional	$N=198$ Latino adults, mean age 20.59, men ($n=59$), women ($n=139$)	BMI	Obesity	Perceived Ethnic Discrimination Questionnaire	Yes
79	Manns-James et al. 2021	Cross-sectional	$N=136$ AA collegiate women aged 18–25	BMI, Waist circumference	Obesity	Everyday Discrimination Scale	Yes
80	Chae et al. 2014	Cross-sectional	$N=92$ AA men aged 30–50	Leukocyte telomere length	Metabolic syndrome and CVD	Experiences of Discrimination Scale	Yes
81	Shin et al. 2017	Cross-sectional	$N=178$ adult women, AA ($n=130$), Hispanic/Latina ($n=48$), mean age 45.3	SBP, DBP, BMI	CMD	Experiences of Discrimination Scale	No
82	Allen et al. 2019	Cross-sectional	$N=208$ (AA women aged 30–50) in San Francisco Bay area	CRP, IL-6, HbA1c, DBP and SBP	CMD	Experience of Discrimination Scale	Yes
83	Fox et al. 2019	Cross-sectional	$N=5,174$ Hispanic/Latinos, Dominican ($n=534$), Central American ($n=553$), Cuban ($n=775$), Mexican ($n=2080$), Puerto Rican ($n=880$), South American ($n=352$)	HDL, FBG, SBP, DBP, Triglycerides and waist circumference	Metabolic syndrome	Perceived Ethnic Discrimination Questionnaire	No
84	Slopen et al. 2019	Cross-sectional	$N=1,146$ Latino youth, aged 8–16	CRP, Metabolic syndrome score	CMD	Perceived Ethnic Discrimination Questionnaire	Yes, CRP
85	Chae et al. 2020	Cross-sectional	$N=391$ AA young adults (aged 18–30)	Leukocyte telomere length	Metabolic syndrome and CVD	Experiences of Discrimination Scale	Yes
86	Nguyen et al. 2018	Cross-sectional	$N=1621$ Caribbean Black adults, men ($n=643$), women ($n=978$), mean age 41	Self-report	CKD	Everyday Discrimination Scale	No

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
87	Cobb et al. 2020	Cross-sectional	*N* = 10,973 adults (aged 52–100), White (83%), Black (8%), Latino (7%) and Other race (2%)	Cystatin C and GFR	CKD	Everyday Discrimination Scale	No
88	Everage et al. 2012	Longitudinal	*N* = 1,362 AA, men (*n* = 571) and women (*n* = 791) aged 33 to 45	CAC, HDL, and BP	CVD	Experiences of Discrimination Scale	Yes, CAC only
89	Beaty-Moody et al. 2014	Longitudinal	*N* = 2,490 women (49% White, 24.6% Black)	C-reactive protein (CRP)	CVD	Everyday Discrimination Scale	No
90	Brody et al. 2015	Longitudinal	*N* = 496, AA youth ages 17–19	IL1, 1L6, 1L8, 1L10, TNF alpha	Systemic Inflammation and CVD	Schedule of Racist Events QSTNAIR	Yes
91	Everson-Rose et al. 2015	Longitudinal	*N* = 6,508 adults, White (39%), Black (26.4%), Hispanic (22.3%), Chinese (12.2%)	Coronary revascularization	Incident CVD	Lifetime Discrimination Scale and Everyday Discrimination Scale	No
92	Dunlay et al. 2017	Longitudinal	*N* = 5,085 AA adults, men (36.5%), women (63.4%), mean age 55.3	Self-reported CV outcomes	CVD	Everyday Discrimination Scale, Lifetime Discrimination Scale and Burden of Lifetime Discrimination Scale	No
93	Udo and Grillo 2017	Longitudinal	*N* = 26,992 Adults, men (*n* = 12,011), women (*n* = 14,981), NH White (57.5%), NH Black (20%) and Hispanic (18.9%)	Self-reported CVD	CVD	Experiences with Discrimination Scale	Yes
94	Bey et al. 2019	Longitudinal	*N* = 3,758 (Black or White adults)	Self-reported measure	CVD	Experience of Discrimination Scale	Yes
95	Sims et al. 2020	Longitudinal and cross-sectional	*N* = 5,145 AA, men (*n* = 1,898), women (*n* = 3,247), aged 21–92	CRP	CVD	Jackson Heart Study Discrimination Instrument	Yes
96	Barr et al. 2022	Longitudinal	*N* = 263 AA adult couples aged 20–87	Self-reported SBP, HDL and cholesterol	CVD	Schedule of Racist Events	Yes
97	Cozier et al. 2006	Longitudinal	*N* = 30,330 US Black women (median age of 37)	Self-reported Incident BP	HTN	Everyday Discrimination Scale adapted	Yes
98	Brondolo et al. 2008	Longitudinal	*N* = 357, 217 Black and 140 Latino(a), aged 20–65	SBP, DBP and HR	HTN	Perceived Ethnic Discrimination Questionnaire	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
99	Beaty-Moody et al. 2019	Longitudinal	$N=2,180$ (Black, White, Hispanic, Chinese, and Japanese)	SBP and DBP	HTN	Everyday Discrimination Scale	No
100	Forde et al. 2020	Longitudinal	$N=1,845$ AA adults (aged 21–85), women (61.1%), men (38.9%)	SBP and DBP	HTN	Everyday Discrimination Scale and Lifetime Discrimination Scale	Yes
101	Forde et al. 2021	Longitudinal	$N=3,297$ adults aged 45–84, White ($n=1454$), Black ($n=626$), Hispanic ($n=743$), Chinese ($n=474$)	SBP, DBP	HTN	Everyday Discrimination Scale and Lifetime Discrimination Scale	Yes, for Black participants
102	Bacon et al. 2017	Longitudinal	$N=45,781$ (AA women aged 21–69)	BMI	Type 2 Diabetes	Everyday Discrimination Scale	Yes
103	Whitaker et al. 2017	Longitudinal	$N=5,310$ adults, AA ($n=1,300$), White ($n=2,266$), Hispanic ($n=1,103$), Chinese ($n=641$), men ($n=2,484$) and women ($n=2,826$)	FBG, self-reported diabetes	Type 2 Diabetes	Major Experiences of Discrimination Scale and Everyday Discrimination Scale	Yes
104	Mayne et al. 2020	Longitudinal	$N=2,175$ Black adults	HbA1c, FBG, oral tolerance test	Diabetes	Experiences of Discrimination scale	No
105	Gaston et al. 2021	Longitudinal	$N=33,833$ women, NH White ($n=30,409$), NH Black ($n=2,435$), Hispanic/Latina ($n=989$), mean age 54.9	Self-report	Type 2 Diabetes	Everyday Discrimination Scale	Yes, for major discrimination only
106	Cozier et al. 2014	Longitudinal	$N=12,810$ US Black women (mean age of 31.9), mean BMI of 24.3	BMI	Obesity	Everyday Discrimination Scale adapted	Yes
107	Cunningham et al. 2012	Longitudinal	$N=3,336$, [Black women $n=901$, Black men $n=614$, White women $n=958$, and White men $n=863$]	CRP	CMD	Experiences of Discrimination Scale	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
108	Beaty-Moody et al. 2018	Longitudinal	*N* = 2,132 adults, [Black (*n* = 523), White (*n* = 1,065), Hispanic (*n* = 123), Chinese (*n* = 194), Japanese (*n* = 227)]	BP, Fasting blood glucose (FBG), HDL	Metabolic syndrome	Everyday Discrimination Scale	Yes
109	Boen 2020	Longitudinal	*N* = 7,280 (age 50 >), Black (*n* = 1,004), White (*n* = 6,276)	CRP, BP, HbA1C and HDL	Metabolic dysregulation	Self-reported measure	Yes
110	Cardel et al. 2020	Longitudinal	*N* = 3,870 AA adults ages 21–95 (63.1% women, 36.9% men)	Triglycerides, HDL and FBG	Metabolic syndrome	Everyday Discrimination Scale	Yes
111	Beydoun et al. 2017	Longitudinal	*N* = 1,620 (662 Whites and 985 AA, aged 30–64)	Glomerular filtration rate (GFR)	CKD	Self-reported measure	Yes
112	Lunyera et al. 2018	Longitudinal	*N* = 3,390 Black American, men (*n* = 1,266), women (*n* = 2,124), mean age 55	GFR, albumin-creatinine ratio	CKD	Jackson Heart Study Discrimination Instrument	No
113	Guyll et al. 2001	Quasi-experimental	*N* = 363 adult women, AA (*n* = 101), EA (*n* = 262), mean age 45.5	SBP, DBP, HR	CVD	Everyday Discrimination Scale	Yes
114	Lepore et al. 2006	Quasi-Experimental	*N* = 80 women aged 16–41, Black (*n* = 40), White (*n* = 40)	SBP, DBP and HR	CVD	Simulated Racial Discrimination and self-report	Yes
115	Hoggard et al. 2015	Quasi-Experimental	*N* = 42 AA women college students, mean age 19.83	HRV, HR	CVD	Simulated Racial Discrimination, Impact of Event Scale	Yes
116	Lucas et al. 2016	Quasi-Experimental	*N* = 118 AA adults, men (*n* = 36), women (*n* = 82), aged 18–63	Salivary Cortisol and CRP	CVD	Self-reported measure	Yes
117	Lucas et al. 2017	Quasi-Experimental	*N* = 85 AA adults, men (*n* = 21), women (*n* = 64)	CRP, DHEA, alpha amylase, cortisol	CVD	Everyday Discrimination Scale	Yes

Table 1 (continued)

	Author (Year)	Study design	Population size and sample	CMD biomarkers	CMD risk/outcome	Discrimination measure	Association between racial/ethnic discrimination and CMD
118	Hermosura et al. 2018	Quasi-Experimental	*N* = 35 Native Hawaiian, women (*n* = 27), men (*n* = 8), aged 18–30	SBP, DBP and Heart Rate	Cardiovascular reactivity	Perceived Ethnic Discrimination Questionnaire, Lifetime Exposure Scale and the Modified Oppression Questionnaire	Yes
119	Saban et al. 2018	Quasi-Experimental	*N* = 99 postmenopausal women (50 AA and 49 non-Hispanic White) aged 50–75	IL-6 and CRP	CVD	Detroit Area Study Discrimination Scale (DAS-DS)	No
120	Sladek et al. 2021	Quasi-experimental	*N* = 84 U.S Latino adolescents, men (*n* = 31), women (*n* = 53), mean age 18.56	MAP, Salivary cortisol	CVD	Self-reported discrimination	Yes
121	Meritt et al. 2006	RCT	*N* = 73 Black men, aged 18–47	SBP, DBP and HR	HTN, cardiovascular response	Racist stressor experiment followed by self-report	Yes
122	Arriola et al. 2021	RCT	*N* = 52 AA adults aged 25–65, men (*n* = 21), women (*n* = 31)	IL6, SBP, DBP	CKD	Race-Based Rejection Sensitivity Questionnaire	Yes
123	Tull and Chambers 2001	Case–control	*N* = 82 Black adults, men (*n* = 37) and women (*n* = 45), mean age 59	Fasting blood glucose	Type 2 Diabetes	Nadanolitization Scale	Yes

CVD = Cardiovascular disease; *CKD* = Chronic kidney disease; *CMD* = Cardiometabolic disease; *HTN* = Hypertension; *SBP* = Systolic blood pressure; *DBP* = Diastolic blood pressure; *CAC* = Coronary artery calcification; *CRP* = C-reactive protein; *MAP* = Mean arterial pressure; *HR* = Heart rate; *HRV* = Heart rate variability; *FBG*=Fasting blood glucose; *HbA1C* = Hemoglobin A1C; *IL* = Interleukins; *TNF* = Tumor necrosis factor; *HDL* = High density lipoproteins; *LDL* = Low density lipoproteins; *GFR* = Glomerular filtration rate; *BMI* = Body mass index; *DHEA* = Dehydroepiandrosterone; *RBC* = Red blood cell; *SLC4A5 gene* = Electrogenic sodium bicarbonate cotransporter 4; *ABP* = Ambulatory blood pressure; *MCP* = monocyte chemoattractant protein; *AA* = African American; *NH* = non-Hispanic; *EA* = European American; *US* = United States of America

Table 2 Frequency and association of cardiometabolic disease and biomarkers across studies

Cardiometabolic disease and biomarkers ($N=123$ studies)	Cross-sectional study ($n=87$)	Positive association ($n=61$)	Longitudinal study ($n=25$)	Positive association ($n=19$)	Quasi-experimental study ($n=8$)	Positive association ($n=7$)	Other ($n=3$)	Positive association ($n=3$)	Total significant association ($n=90$)
CVD ($n=40$)	23	21	9	6	8	7	0	0	34
Hypertension ($n=46$)	40	25	5	4	0	0	1	1	30
Diabetes ($n=11$)	6	4	4	3	0	0	1[a]	1	8
Obesity ($n=12$)	11	8	1	1	0	0	0	0	9
Metabolic syndrome ($n=9$)	5	3	4	4	0	0	0	0	7
CKD ($n=5$)	2	0	2	1	0	0	1	1	2
Biomarkers									
SBP and DBP	40		7		4		1		38
Mean arterial pressure (MAP)	3		0		1		0		2
C-reactive protein (CRP)	5		4		3		0		9
CAC	3		1		0		0		3
HbA1c	4		2		0		0		2
HDL, LDL, Triglycerides	2		5		0		0		5
IL1, 1L6, 1L8, 1L10, TNF alpha	2		1		2		0		4
Heart rate (HR), HR Variability	7		1		4		1		11
Fasting blood glucose (FBG)	4		4		0		1		6
Leukocyte telomere length	3		0		0		0		3
BMI	15		2		0		0		13
Plasma endothelin 1	2		0		0		0		2
GFR	1		2		0		0		1
Cystatin C	1		0		0		0		
α1 and þ adrenergic receptors	1		0		0		0		1
Salivary cortisol, cortisol	2		0		3		0		5
DHEA	0		0		1		0		1
Alpha amylase	0		0		1		0		1
RBC heme degradation	1		0		0		0		1
SLC4A5 gene	1		0		0		0		1
Waist circumference	3		0		0		0		2
Carotid artery intima-media thickness	2		0		0		0		2
Fasting insulin	1		0		0		0		1

CVD = Cardiovascular disease; *CKD* = Chronic kidney disease; *SBP* = Systolic blood pressure; *DBP* = Diastolic blood pressure; *CAC* = Coronary artery calcification; *HbA1C* = Hemoglobin A1C; *IL* = Interleukins; *TNF* = Tumor necrosis factor; *HDL* = High density lipoproteins; *LDL* = Low density lipoproteins; *GFR* = Glomerular filtration rate; *BMI* = Body mass index; *DHEA* = Dehydroepiandrosterone; *RBC* = Red blood cell; *SLC4A5 gene* = Electrogenic sodium bicarbonate cotransporter 4; *Other* = Randomized controlled trial (RCT) or Case–control study ([a] denotes case–control study focus)

pressure (DBP) were the most frequently used ($n=52$) biomarkers reported in cross sectional ($n=40$), longitudinal ($n=7$), quasi-experimental ($n=4$), and randomized controlled trial ($n=1$) studies (Table 2). C-reactive protein (CRP), a marker of inflammation, was one of the most frequently analyzed biomarkers ($n=12$) in cross sectional ($n=5$), longitudinal ($n=4$), and quasi-experimental ($n=3$) studies. Other biomarkers examined were body mass index (BMI, $n=17$), heart rate (HR/HR variability, $n=13$), fasting blood glucose (FBG, $n=9$), hemoglobin A1c (HbA1c, a blood sugar marker, $n=6$), coronary artery calcification (CAC, $n=3$), leukocyte telomere length (nucleoproteins that cap chromosomes, $n=3$), glomerular filtration rate (GFR, assesses kidney function, $n=3$), plasma endothelin 1 (a vasoconstrictor peptide, $n=2$), and Solute Carrier Family 4 Member 5 (SLC4A5 gene, associated with cardiometabolic phenotypes, $n=1$).

Across several studies, a significant positive association between racial/ethnic discrimination and biomarkers of CMD was observed, with SBP and DBP ($n=38$) found to be the most frequently associated with experiences of racial/ethnic discrimination, followed by BMI ($n=13$), HR/HR variability ($n=10$) and CRP ($n=9$). Table 2 details the frequency and associations of CMD biomarkers and their distribution across study designs.

Discussion

This review provides an overview of the relationship between racial/ethnic discrimination and CMD among racial/ethnic minority groups in the United States. To the best of our knowledge, this review is the first to assess association between CMD and CMD biomarkers and to relate them to measures of discrimination. Overall, the evidence reviewed here suggests that there is a significant positive association between experiences of racial/ethnic discrimination and CMD, with 73.2% of studies finding significant links. Previous systematic reviews also suggest that there is a significant relationship between racial discrimination and cardiovascular health [24, 30]. One of the previous reviews identified 15 eligible articles (sample size range = 69–4,694 participants) exploring the association between racial discrimination and hypertension among African Americans, with 60% of the studies finding a positive association. Similarly, the other identified 84 articles (sample size range = 27–26,992 participants) examining the links between stigma/discrimination and CVD risk factors, with 86% of the studies finding a significant association among socially stigmatized/discriminated groups. The current findings corroborate and extend previous work reporting a strong positive association between discrimination and CVD risk [24, 30, 31]. The current review also examined CMD, expanding the focus to include metabolic dysfunctions, such as diabetes, obesity, chronic kidney disease, and metabolic syndrome. In addition, this review explored CMD biomarkers sensitive to discrimination as well as reviewed substantially more articles, increasing the overall population sample size, and additional measures of discrimination, with the majority of studies finding a positive association. Such results suggest that the processes that contribute to CMD are highly sensitive to significant stress and burden from experiences of racial/ethnic discrimination. Many of the studies included in this review were completed in the last decade, underscoring that racial/ethnic discrimination and CMDs remain pressing public health problems that need to be addressed.

Although studies with different racial/ethnic groups have been reported, African Americans were the most frequently studied group. Given that African Americans are the largest U.S. racial minority group [156], the frequency of CMD in African Americans, as well as the extent of racial discrimination and health inequities, this focus is important. However, important gaps in the literature remain. For example, there was limited evaluation of subgroup differences by race and ancestry, and there were few studies that examined in depth the impact of racial discrimination in many other racial/ethnic minorities, such as Hispanics/Latinos, Asians, Native Hawaiians, American Indians, and persons with multiple races. Additional work in these areas is urgently required.

Racism is embedded within structures and systems that support or facilitate experiences with discrimination. Dismantling such systems and structures is necessary to reduce exposure to discrimination, and thus aid in reducing CMD disparities borne by racial/ethnic minorities. Certainly, efforts to dismantle systemic racism should prioritize policy changes, ranging from creating new equitable policies to enforcing existing antidiscrimination laws [157]. Limited research has been conducted on the association of structural racism and/or systemic racial/ethnic discrimination and CMD, with the majority of studies in this review examining perceived experiences of discrimination. It is essential for future research to examine this association to improve understanding and inform policies that can eliminate systemic/structural barriers to optimum cardiometabolic health, as systemic and structural racism has been linked to adverse health outcomes [23].

Most studies were observational (Table 1); thus, causal effects cannot be determined. However, nineteen longitudinal studies [34, 36–41, 48–50, 52, 55, 56, 90, 100, 104, 108, 112, 115], seven quasi-experimental studies [60, 64, 70, 75, 77, 111, 118], and two randomized controlled trials [80, 110] provide supporting evidence for temporality and causation. Results of these studies were consistent with the cross-sectional findings; however, some observational studies found positive associations for African American women but not men [85] and an

increase in diastolic but not systolic blood pressure [61, 72]. Also, many studies that did not find a significant association between racial/ethnic discrimination and CMD utilized small sample sizes, thus the potential for underpowered studies may explain these differences. This systematic review highlights the need for more longitudinal, prospective cohort, and randomized controlled trial studies to comprehensively measure experiences of racial/ethnic discrimination and establish links to CMDs over time. Specifically, studies that consistently employ large sample sizes and the same standardized measures and/or markers of racial/ethnic discrimination and CMD will be important going forward.

Our review of CMD biomarkers sensitive to racial/ethnic discrimination exposure can contribute to improving detection and understanding of the pathogenesis of CMD among racial/ethnic minorities. Consequently, such understanding may aid in the prevention of CMD and complications among racial/ethnic populations exposed to discrimination. Blood pressure and inflammatory biomarkers were most frequently associated with CMD related to experiences of racial/ethnic discrimination, supporting previous findings that chronic stress from racial/ethnic discrimination increases inflammation and results in wear and tear of bodily systems [26, 27]. Also, genetic and novel biomarkers, such as SLC4A5 gene [95], plasma endothelin 1 gene [59], leukocyte telomere length [74] and RBC heme degradation [94], were demonstrated to be potential predictors of CMD risks among racial/ethnic minorities who reported experiences of racial/ethnic discrimination. The objectivity and reliability of biomarkers support their increased use as risk assessment tools for predicting CMD due to experiences of racial/ethnic discrimination.

Limitations

Some limitations of the review warrant consideration. First, we only included studies published in English. Second, we employed specific search terms, used particular databases, and set a defined timeframe. Thus, expanding the search terms or including publications in other languages, from other databases, or after our timeline might yield additional articles not included in this review. Despite these limitations, the review employed over 100 peer reviewed publications to contextualize understanding of racial/ethnic discrimination-related CMD risk, with a focus on cardiometabolic biomarkers.

Conclusions

In summary, the existing literature suggests that experiences of racial/ethnic discrimination are associated with increased risk of CMD, with findings relatively consistent across varying study designs, samples, and measures. This result indicates that a culturally-sensitive approach to CMD prevention and one informed by the many ways racial/ethnic minorities experience discrimination is necessary. The inclusion of experiences with racial/ethnic discrimination in clinical assessment may be critical in detecting CMD early and in prevention or improved prognosis for racial/ethnic minorities.

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Declarations

Competing Interest The authors have no relevant financial or non-financial interests to disclose.

References

1. Slopen N, Goodman E, Koenen KC, Kubzansky LD. Socioeconomic and other social stressors and biomarkers of cardiometabolic risk in youth: A systematic review of less studied risk factors. PLoS One. 2013;8(5):e64418. https://doi.org/10.1371/journal.pone.0064418.
2. Kim CW, Aronow WS, Frishman WH. Coronavirus disease 2019 and cardiometabolic disease. Cardiol Rev. 2022;30(3):123–8. https://doi.org/10.1097/CRD.0000000000000405.
3. Riggs DW, Yeager RA, Bhatnagar A. Defining the human environome: An omics approach for assessing the environmental risk of cardiovascular disease. Circ Res. 2018;122(9):1259–75. https://doi.org/10.1161/CIRCRESAHA.117.311230.
4. Carnethon MR, Pu J, Howard G, Albert MA, Anderson CAM, Bertoni AG, et al. Cardiovascular health in African Americans: A scientific statement from the American Heart Association. Circulation. 2017;136(21):e393–423. https://doi.org/10.1161/CIR.0000000000000534.
5. Muncan B. Cardiovascular disease in racial/ethnic minority populations: Illness burden and overview of community-based interventions. Public Health Rev. 2018:39(32). https://doi.org/10.1186/s40985-018-0109-4.
6. Havranek EP, Mujahid MS, Barr DA, Blair IV, Cohen MS, Cruz-Flores Salvador, et al. Social determinants of risk and outcomes for cardiovascular disease. A scientific statement from the American Heart Association. Circulation. 2015;132(9):873–98. https://doi.org/10.1161/CIR.0000000000000228.
7. Kibria GMA, Crispen R, Chowdhury MAB, Rao N, Stennett C. Disparities in absolute cardiovascular risk, metabolic syndrome, hypertension, and other risk factors by income within

racial/ethnic groups among middle-aged and older US people. J Hum Hypertens. 2021;35(7):645. https://doi.org/10.1038/s41371-021-00513-8.
8. National Center for Health Statistics. Health, United States, 2011: with special feature on socioeconomic status and health. Hyattsville (MD): National Center for Health Statistics (US); 2012. https://www.ncbi.nlm.nih.gov/books/NBK98752/. Accessed 18 Mar 2023.
9. Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, et al. Heart disease and stroke statistics—2016 update. A report from the American Heart Association. Circulation. 2016;133(4):e38–360. https://doi.org/10.1161/CIR.0000000000000350.
10. Daw J. Contribution of four comorbid conditions to racial/ethnic disparities in mortality risk. Am J Prev Med. 2017;52(1S1):S95–102. https://doi.org/10.1016/j.amepre.2016.07.036.
11. Graham G. Disparities in cardiovascular disease risk in the United States. Curr Cardiol Rev. 2015;11(3):238–45. https://doi.org/10.2174/1573403x11666141122220003.
12. Shaw PM, Chandra V, Escobar GA, Robbins N, Rowe V, Macsata R. Controversies and evidence for cardiovascular disease in the diverse Hispanic population. J Vasc Surg. 2018;67(3):960–9. https://doi.org/10.1016/j.jvs.2017.06.111.
13. Volgman AS, Palaniappan LS, Aggarwal NT, Gupta M, Khandelwal A, Krishnan AV, et al. Atherosclerotic cardiovascular disease in South Asians in the United States: Epidemiology, risk factors, and treatments: A scientific statement from the American Heart Association. Circulation. 2018;138(1):e1–34. https://doi.org/10.1161/CIR.0000000000000580.
14. Bhatnagar A. Environmental determinants of cardiovascular disease. Circ Res. 2017;121(2):62–80. https://doi.org/10.1161/CIRCRESAHA.117.306458.
15. Kurian AK, Cardarelli KM. Racial and ethnic differences in cardiovascular disease risk factors: a systematic review. Ethn Dis. 2007;17(1):143–52.
16. Churchwell K, Elkind MSV, Benjamin RM, Carson AP, Chang EK, Lawrence W, et al. Call to action: Structural racism as a fundamental driver of health disparities: A presidential advisory from the American Heart Association. Circulation. 2020;142(24):e454–68. https://doi.org/10.1161/CIR.0000000000000936.
17. Centers for Disease Control and Prevention. Racism and health.https://www.cdc.gov/healthequity/racism-disparities/index.html. 2021. Accessed Aug 10, 2021.
18. Priest N, Truong M, Chong S, Paredies Y, King TL, Kavanagh A, et al. Experiences of racial discrimination and cardiometabolic risk among Australian children. Brain Behav Immun. 2020;87:660–5. https://doi.org/10.1016/j.bbi.2020.02.012.
19 Jones CP. Confronting institutionalized racism. Phylon (1960-). 2002;50(1/2):7–22. https://doi.org/10.2307/4149999.
20. Harrell SP. A multidimensional conceptualization of racism-related stress: Implications for the well-being of people of color. Am J Orthopsychiatry. 2000;70(1):42–57. https://doi.org/10.1037/h0087722.
21. Wyatt SB, Williams DR, Calvin R, Henderson FC, Walker ER, Winters K. Racism and cardiovascular disease in African Americans. Am J Med Sci. 2003;325(6):315–31. https://doi.org/10.1097/00000441-200306000-00003.
22 Williams DR, Lawrence JA, Davis BA, Vu C. Understanding how discrimination can affect health. Health Serv Res. 2019;54:1374–88. https://doi.org/10.1111/1475-6773.13222.
23. Williams DR, Lawrence JA, Davis BA. Racism and health: Evidence and needed research. Annu Rev Public Health. 2019;40:105–25. https://doi.org/10.1146/annurev-publhealth-040218-043750.
24. Cuffee YL, Hargraves LJ, Allison J. Exploring the association between reported discrimination and hypertension among African Americans: a systematic review. Ethn Dis. 2012;22(4):422–31.
25. Mays VM, Cochran SD, Barnes NW. Race, race-based discrimination, and health outcomes among African Americans. Annu Rev Psychol. 2007;58:201–25. https://doi.org/10.1146/annurev.psych.57.102904.190212.
26. Black PH, Garbutt LD. Stress, inflammation and cardiovascular disease. J Psychosom Res. 2002;52(1):1–23. https://doi.org/10.1016/s0022-3999(01)00302-6.
27. Goosby BJ, Straley E, Cheadle JE. Discrimination, sleep, and stress reactivity: Pathways to African American-White cardiometabolic risk inequities. Popul Res Policy Rev. 2017;36:699–716. https://doi.org/10.1007/s11113-017-9439-z.
28. Vasan RS. Biomarkers of cardiovascular disease: Molecular basis and practical considerations. Circulation. 2006;113(19):2335–62. https://doi.org/10.1161/CIRCULATIONAHA.104.482570.
29. Lyons TJ, Basu A. Biomarkers in diabetes: Hemoglobin A1c, vascular and tissue markers. Transl Res. 2012;159(4):303–12. https://doi.org/10.1016/j.trsl.2012.01.009.
30. Panza GA, Puhl RM, Taylor BA, Zaleski AL, Livingston J, Pescatello LS. Links between discrimination and cardiovascular health among socially stigmatized groups: A systematic review. PLoS One. 2019;14(6):e0217623. https://doi.org/10.1371/journal.pone.0217623.
31. Dolezsar CM, McGrath JJ, Herzig AJM, Miller SB. Perceived racial discrimination and hypertension: A comprehensive systematic review. Health Psychol. 2014;33(1):20–34. https://doi.org/10.1037/a0033718.
32. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev. 2015;4(1):1. https://doi.org/10.1186/2046-4053-4-1.
33. Allen AM, Thomas MD, Michaels EK, Reeves AN, Okoye U, Price MM, et al. Racial discrimination, educational attainment, and biological dysregulation among midlife African American women. Psychoneuroendocrinol. 2019;99:225–35. https://doi.org/10.1016/j.psyneuen.2018.09.001.
34. Bacon KL, Stuver SO, Cozier YC, Palmer JR, Rosenberg L, Ruiz-Narváez EA. Perceived racism and incident diabetes in the Black Women's Health Study. Diabetologia. 2017;60(11):2221–5. https://doi.org/10.1007/s00125-017-4400-6.
35. Beatty Moody DL, Waldstein SR, Tobin JN, Cassells A, Schwartz JC, Brondolo E. Lifetime racial/ethnic discrimination and ambulatory blood pressure: The moderating effect of age. Health Psychol. 2016;35(4):333–42. https://doi.org/10.1037/hea0000270.
36. Beatty Moody DL, Chang Y, Brown C, Bromberger JT, Matthews KA. Everyday discrimination and metabolic syndrome incidence in a racially/ethnically diverse sample: Study of Women's Health Across the Nation (SWAN). Psychosom Med. 2018;80(1):114–21. https://doi.org/10.1097/PSY.0000000000000516.
37. Bey GS, Jesdale B, Forrester S, Person SD, Kiefe C. Intersectional effects of racial and gender discrimination on cardiovascular health vary among Black and White women and men in the CARDIA study. SSM Popul Health. 2019;8:100446. https://doi.org/10.1016/j.ssmph.2019.100446.
38. Beydoun MA, Poggi-Burke A, Zonderman AB, Rostant OS, Evans MK, Crews DC. Perceived discrimination and longitudinal change in kidney function among urban adults. Psychosom Med. 2017;79(7):824–34. https://doi.org/10.1097/PSY.0000000000000478.
39. Brody GH, Yu T, Miller GE, Chen E. Discrimination, racial identity, and cytokine levels among African American adolescents. J

Adolesc Health. 2015;56(5):496–501. https://doi.org/10.1016/j.jadohealth.2015.01.017.
40. Brondolo E, Libby DJ, Ge Denton E, Thompson S, Beatty DL, Schwartz J, et al. Racism and ambulatory blood pressure in a community sample. Psychosom Med. 2008;70(1):49–56. https://doi.org/10.1097/PSY.0b013e31815ff3bd.
41. Cardel MI, Chi X, Min Y-I, Sims M, Musani SK, Dulin A, et al. Experiences of discrimination are associated with worse metabolic syndrome severity among African Americans in the Jackson Heart Study. Ann Behav Med. 2021;55(3):266–79. https://doi.org/10.1093/abm/kaaa050.
42. Cardarelli R, Cardarelli KM, Fulda KG, Espinoza A, Cage C, Vishwanatha J, et al. Self-reported racial discrimination, response to unfair treatment, and coronary calcification in asymptomatic adults–the North Texas Healthy Heart study. BMC Public Health. 2010;10:285. https://doi.org/10.1186/1471-2458-10-285.
43. Chae DH, Nuru-Jeter AM, Lincoln KD, Jacob Arriola KR. Racial discrimination, mood disorders, and cardiovascular disease among Black Americans. Ann Epidemiol. 2012;22(2):104–11. https://doi.org/10.1016/j.annepidem.2011.10.009.
44. Chae DH, Nuru-Jeter AM, Adler NE, Brody GH, Lin J, Blackburn EH, et al. Discrimination, racial bias, and telomere length in African-American men. Am J Prev Med. 2014;46(2):103–11. https://doi.org/10.1016/j.amepre.2013.10.020.
45. Chae DH, Wang Y, Martz CD, Slopen N, Yip T, Adler NE, et al. Racial discrimination and telomere shortening among African Americans: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. Health Psychol. 2020;39(3):209–19. https://doi.org/10.1037/hea0000832.
46. Clark R. Perceptions of interethnic group racism predict increased vascular reactivity to a laboratory challenge in college women. Ann Behav Med. 2000;22(3):214–22. https://doi.org/10.1007/BF02895116.
47. Cooper DC, Mills PJ, Bardwell WA, Ziegler MG, Dimsdale JE. The effects of ethnic discrimination and socioeconomic status on endothelin-1 among Blacks and Whites. Am J Hypertens. 2009;22(7):698–704. https://doi.org/10.1038/ajh.2009.72.
48. Boen C. Death by a thousand cuts: Stress exposure and Black-White disparities in physiological functioning in late life. J Gerontol B Psychol Sci Soc Sci. 2020;75(9):1937–50. https://doi.org/10.1093/geronb/gbz068.
49. Cozier Y, Palmer JR, Horton NJ, Fredman L, Wise LA, Rosenberg L. Racial discrimination and the incidence of hypertension in US Black women. Ann Epidemiol. 2006;16(9):681–7. https://doi.org/10.1016/j.annepidem.2005.11.008.
50. Cozier YC, Yu J, Coogan PF, Bethea TN, Rosenberg L, Palmer JR. Racism, segregation, and risk of obesity in the Black Women's Health Study. Am J Epidemiol. 2014;179(7):875–83. https://doi.org/10.1093/aje/kwu004.
51. Cuevas AG, Ortiz K, Ransome Y. The moderating role of race/ethnicity and nativity in the relationship between perceived discrimination and overweight and obesity: Results from the National Epidemiologic Survey on Alcohol and Related Conditions. BMC Public Health. 2019;19(1):1458. https://doi.org/10.1186/s12889-019-7811-0.
52. Cunningham TJ, Seeman TE, KawachI I, Gortmaker SL, Jacobs DR, Kiefe CI, et al. Racial/ethnic and gender differences in the association between self-reported experiences of racial/ethnic discrimination and inflammation in the CARDIA cohort of 4 US communities. Soc Sci Med. 2012;75(5):922–31. https://doi.org/10.1016/j.socscimed.2012.04.027.
53. Dawson AZ, Walker RJ, Campbell JA, Egede LE. Effect of perceived racial discrimination on self-care behaviors, glycemic control, and quality of life in adults with type 2 diabetes. Endocrine. 2015;49(2):422–8. https://doi.org/10.1007/s12020-014-0482-9.
54 Din-Dzietham R, Nembhard WN, Collins R, Davis SK. Perceived stress following race-based discrimination at work is associated with hypertension in African-Americans. The Metro Atlanta heart disease study, 1999–2001. Soc Sci Med. 2004;58(3):449–61. https://doi.org/10.1016/s0277-9536(03)00211-9.
55. Everage NJ, Gjelsvik A, McGarvey ST, Linkletter CD, Loucks EB. Inverse associations between perceived racism and coronary artery calcification. Ann Epidemiol. 2012;22(3):183–90. https://doi.org/10.1016/j.annepidem.2012.01.005.
56. Forde AT, Sims M, Muntner P, Lewis T, Onwuka A, Moore K, et al. Discrimination and hypertension risk among African Americans in the Jackson Heart Study. Hypertension. 2020;76(3):715–23. https://doi.org/10.1161/HYPERTENSIONAHA.119.14492.
57. Giurgescu C, Engeland CG, Templin TN, Zenk SN, Koenig MD, Garfield L. Racial discrimination predicts greater systemic inflammation in pregnant African American women. Appl Nurs Res. 2016;32:98–103. https://doi.org/10.1016/j.apnr.2016.06.008.
58. Goosby BJ, Malone S, Richardson EA, Cheadle JE, Williams DT. Perceived discrimination and markers of cardiovascular risk among low-income African American youth. Am J Hum Biol. 2015;27(4):546–52. https://doi.org/10.1002/ajhb.22683.
59. Gregoski MJ, Buxbaum SG, Kapuku G, Dong Y, Zhu H, Davis M, et al. Interactive influences of ethnicity, endothelin-1 gene, and everyday discrimination upon nocturnal ambulatory blood pressure. Ann Behav Med. 2013;45(3):377–86. https://doi.org/10.1007/s12160-013-9472-z.
60. Hermosura AHo, Haynes SN, Kaholokula JKa. A preliminary study of the relationship between perceived racism and cardiovascular reactivity and recovery in Native Hawaiians. J Racial Ethn Health Disparities. 2018;5(5):1142–54. https://doi.org/10.1007/s40615-018-0463-4.
61. Hill LK, Kobayashi I, Hughes JW. Perceived racism and ambulatory blood pressure in African American college students. J Black Psychol. 2007;33(4):404–21. https://doi.org/10.1177/0095798407307042.
62. Hill LK, Hoggard LS, Richmond AS, Gray DL, Williams DP, Thayer JF. Examining the association between perceived discrimination and heart rate variability in African Americans. Cultur Divers Ethnic Minor Psychol. 2017;23(1):5–14. https://doi.org/10.1037/cdp0000076.
63. Hill LK, Sherwood A, McNeilly M, Anderson NA, Blumenthal JA, Hinderliter AL. The impact of racial discrimination and hostility on adrenergic receptor responsiveness in African Americans. Psychosom Med. 2018;80(2):208–15. https://doi.org/10.1097/PSY.0000000000000547.
64. Hoggard LS, Hill LK, Gray DL, Sellers RM. Capturing the cardiac effects of racial discrimination: Do the effects "keep going"? Int J Psychophysiol. 2015;97(2):163–70. https://doi.org/10.1016/j.ijpsycho.2015.04.015.
65. Ing CT, Antonio M, Jun Ahn H, Cassel K, Dillard A, Kekauoha BP, et al. An examination of the relationship between discrimination, depression, and hypertension in Native Hawaiians. Asian Am J Psychol. 2019;10(3):249–57. https://doi.org/10.1037/aap0000151.
66. Kaholokula JK, Grandinetti A, Keller S, Nacapoy AH, Kingi TK, Mau MK. Association between perceived racism and physiological stress indices in Native Hawaiians. J Behav Med. 2012;35(1):27–37. https://doi.org/10.1007/s10865-011-9330-z.
67. Klimentidis YC, Dulin-Keita A, Casazza K, Willig AL, Allison DB, Fernandez JR. Genetic admixture, social–behavioural factors and body composition are associated with blood pressure differently by racial–ethnic group among children. J Hum Hypertens. 2012;26(2):98–107. https://doi.org/10.1038/jhh.2010.130.
68. Krieger N, Sidney S. Racial discrimination and blood pressure: The CARDIA study of young Black and White adults. Am J

Public Health. 1996;86(10):1370–8. https://doi.org/10.2105/ajph.86.10.1370.
69. LeBrón AMW, Schulz AJ, Mentz G, Reyes AG, Gamboa C, Israel BA, et al. Impact of change over time in self-reported discrimination on blood pressure: Implications for inequities in cardiovascular risk for a multi-racial urban community. Ethn Health. 2018;1–19. https://doi.org/10.1080/13557858.2018.1425378.
70. Lepore SJ, Revenson TA, Weinberger SL, Weston P, Frisina PG, Robertson R, et al. Effects of social stressors on cardiovascular reactivity in Black and White women. Ann Behav Med. 2006;31(2):120–7. https://doi.org/10.1207/s15324796abm3102_3.
71. Lewis TT, Everson-Rose SA, Powell LH, Matthews KA, Brown C, Karavolos K, et al. Chronic exposure to everyday discrimination and coronary artery calcification in African-American women: The SWAN Heart Study. Psychosom Med. 2006;68(3):362–8. https://doi.org/10.1097/01.psy.0000221360.94700.16.
72. Lewis TT, Barnes LL, Bienias JL, Lackland DT, Evans DA, Mendes de Leon CF. Perceived discrimination and blood pressure in older African American and White adults. J Gerontol A Biol Sci Med Sci. 2009;64(9):1002–8. https://doi.org/10.1093/gerona/glp062.
73. Lewis TT, Aiello AE, Leurgans S, Kelly J, Barnes LL. Self-reported experiences of everyday discrimination are associated with elevated c-reactive protein levels in older African-American adults. Brain Behav Immun. 2010;24(3):438–43. https://doi.org/10.1016/j.bbi.2009.11.011.
74. Lu D, Palmer JR, Rosenberg L, Shields AE, Orr EH, DeVivo I, et al. Perceived racism in relation to telomere length among African American women in the Black Women's Health Study. Ann Epidemiol. 2019;36:33–9. https://doi.org/10.1016/j.annepidem.2019.06.003.
75. Lucas T, Lumley MA, Flack JM, Wegner R, Pierce J, Goetz S. A preliminary experimental examination of worldview verification, perceived racism, and stress reactivity in African Americans. Health Psychol. 2016;35(4):366–75. https://doi.org/10.1037/hea0000284.
76. Drolet CE, Lucas T. Perceived racism, afectivity, and c-reactive protein in healthy African Americans: Do religiosity and racial identity provide complementary protection? J Behav Med. 2020;43(6):932–42. https://doi.org/10.1007/s10865-020-00146-1.
77. Lucas T, Wegner R, Pierce J, Lumley MA, Laurent HK, Granger DA. Perceived discrimination, racial identity, and multisystem stress response to social evaluative threat among African American men and women. Psychosom Med. 2017;79(3):293–305. https://doi.org/10.1097/PSY.0000000000000406.
78. McClure HH, Snodgrass JJ, Martinez CR Jr, Eddy JM, Jiménez RA, Isiordia LE. Discrimination, psychosocial stress, and health among Latin American immigrants in Oregon. Am J Hum Biol. 2010;22(3):421–3. https://doi.org/10.1002/ajhb.21002.
79. McCubbin LD, Antonio M. Discrimination and obesity among Native Hawaiians. Hawaii J Med Public Health. 2012;71(12):346–52.
80. Merritt MM, Bennett GG Jr, Williams RB, Edwards CL, Sollers JJ 3rd. Perceived racism and cardiovascular reactivity and recovery to personally relevant stress. Health Psychol. 2006;25(3):364–9. https://doi.org/10.1037/0278-6133.25.3.364.
81. Mouzon DM, Taylor RJ, Woodward A, Chatters LM. Everyday racial discrimination, everyday non-racial discrimination, and physical health among African-Americans. J Ethn Cult Divers Soc Work. 2016;26(1–2):68–80. https://doi.org/10.1080/15313204.2016.1187103.
82. Mwendwa DT, Sims RC, Madhere S, Thomas J, Keen LD 3rd, Callender CO, et al. The influence of coping with perceived racism and stress on lipid levels in African Americans. J Natl Med Assoc. 2011;103(7):594–601. https://doi.org/10.1016/s0027-9684(15)30385-0.
83. Mwendwa DT, Gholson G, Sims RC, Levy S-A, Ali M, Harrell CJ, et al. Coping with perceived racism: A significant factor in the development of obesity in African American women? J Natl Med Assoc. 2011;103(7):602–8. https://doi.org/10.1016/s0027-9684(15)30386-2.
84. Orom H, Sharma C, Homish GG, Underwood III W, Homish DL. Racial discrimination and stigma consciousness are associated with higher blood pressure and hypertension in minority men. J Racial Ethn Health Disparities. 2016;31. https://doi.org/10.1007/s40615-016-0284-2.
85. Roberts CB, Vines AI, Kaufman JS, James SA. Cross-sectional association between perceived discrimination and hypertension in African-American men and women: The Pitt County Study. Am J Epidemiol. 2008;167(5):624–32. https://doi.org/10.1093/aje/kwm334.
86. Rodriguez CJ, Gwathmey TM, Jin Z, Schwartz J, Beech BM, Sacco RL, et al. Perceived discrimination and nocturnal blood pressure dipping among Hispanics: The influence of social support and race. Psychosom Med. 2016;78(7):841–50. https://doi.org/10.1097/PSY.0000000000000341.
87. Ryan AM, Gee GC, Laflamme DF. The association between self-reported discrimination, physical health and blood pressure: Findings from African Americans, Black immigrants, and Latino immigrants in New Hampshire. J Health Care Poor Underserved. 2006;17(2 Suppl):116–32. https://doi.org/10.1353/hpu.2006.0092.
88. Salomon K, Jagusztyn NE. Resting cardiovascular levels and reactivity to interpersonal incivility among Black, Latina/o, and White Individuals: The moderating role of ethnic discrimination. Health Psychol. 2008;27(4):473–81. https://doi.org/10.1037/0278-6133.27.4.473.
89. Sims M, Diez-Roux AV, Dudley A, Gebreab S, Wyatt SB, Bruce MA, et al. Perceived discrimination and hypertension among African Americans in the Jackson Heart Study. Am J Public Health. 2012;102:S258-65. https://doi.org/10.2105/AJPH.2011.300523.
90. Sims KD, Sims M, Glover LM, Smit E, Odden MC. Perceived discrimination and trajectories of c-reactive protein: The Jackson Heart Study. Am J Prev Med. 2020;58(2):199–207. https://doi.org/10.1016/j.amepre.2019.09.019.
91. Singleton GJ, Robertson J, Robinson J, Austin C, Edochie V. Perceived racism and coping: joint predictors of blood pressure in Black Americans. Negro Edu Rev. 2008;59:93–113.
92. Slopen N, Strizich G, Hua S, Gallo LC, Chae DH, Priest N, et al. Maternal experiences of ethnic discrimination and child cardiometabolic outcomes in the Study of Latino Youth. Ann Epidemiol. 2019;34:52–7. https://doi.org/10.1016/j.annepidem.2019.03.011.
93. Steffen PR, McNeilly M, Anderson N, Sherwood A. Effects of perceived racism and anger inhibition on ambulatory blood pressure in African Americans. Psychosom Med. 2003;65(5):746–50. https://doi.org/10.1097/01.psy.0000079380.95903.78.
94. Szanton SL, Rifkind JM, Mohanty JG, Miller ER 3rd, Thorpe RJ, Nagababu E, et al. Racial discrimination is associated with a measure of red blood cell oxidative stress: A potential pathway for racial health disparities. Int J Behav Med. 2012;19(4):489–95. https://doi.org/10.1007/s12529-011-9188-z.
95. Taylor JY, Sun YV, de Mendoza VB, Ifatunji M, Rafferty J, Fox ER, et al. The combined effects of genetic risk and perceived discrimination on blood pressure among African Americans in the Jackson Heart Study. Medicine (Baltimore). 2017;96(43):e8369. https://doi.org/10.1097/MD.0000000000008369.
96. Thayer ZM, Blair IV, Buchwald DS, Manson SM. Racial discrimination associated with higher diastolic blood pressure in

a sample of American Indian adults. Am J Phys Anthropol. 2017;163(1):122–8. https://doi.org/10.1002/ajpa.23190.
97. Thorpe RJ Jr, Parker LJ, Cobb RJ, Dillard F, Bowie J. Association between discrimination and obesity in African-American men. Biodemography Soc Biol. 2017;63(3):253–61. https://doi.org/10.1080/19485565.2017.1353406.
98. Troxel WM, Matthews KA, Bromberger JT, Sutton-Tyrrell K. Chronic stress burden, discrimination, and subclinical carotid artery disease in African American and Caucasian Women. Health Psychol. 2003;22(3):300–9. https://doi.org/10.1037/0278-6133.22.3.300.
99. Tull ES, Chambers EC. Internalized racism is associated with glucose intolerance among Black Americans in the U.S. Virgin Islands. Diabetes Care. 2001;24(8):1498. https://doi.org/10.2337/diacare.24.8.1498.
100 Udo T, Grilo CM. Cardiovascular disease and perceived weight, racial, and gender discrimination in U.S. adults. J Psychosom Res. 2017;100:83–8. https://doi.org/10.1016/j.jpsychores.2017.07.007.
101. Wagner JA, Tennen H, Feinn R, Finan PH. Racial discrimination and metabolic control in women with type 2 diabetes. Ethn Dis. 2013;23(4):421–7.
102. Wagner J, Lampert R, Tennen H, Feinn R. Exposure to discrimination and heart rate variability reactivity to acute stress among women with diabetes. Stress Health. 2015;31(3):255–62. https://doi.org/10.1002/smi.2542.
103. Wagner J, Tennen H, Finan P, Feinn R, Burg MM, Seawell A, et al. Exposure to racial discrimination and ambulatory blood pressure in women with Type 2 Diabetes. Stress Health. 2016;32(4):337–45. https://doi.org/10.1002/smi.2622.
104. Whitaker KM, Everson-Rose SA, Pankow JS, Rodriguez CJ, Lewis TT, Kershaw KN, et al. Experiences of discrimination and incident type 2 diabetes mellitus: The Multi-Ethnic Study of Atherosclerosis (MESA). Am J Epidemiol. 2017;186(4):445–55. https://doi.org/10.1093/aje/kwx047.
105. Williams DP, Pandya KD, Hill LK, Kemp AH, Way BM, Thayer JF, et al. Rumination moderates the association between resting high-frequency heart rate variability and perceived ethnic discrimination. J Psychophysiol. 2019;33(1):13–21. https://doi.org/10.1027/0269-8803/a000201.
106. Mujahid MS, Diez Roux AV, Cooper RC, Shea S, Williams DR. Neighborhood stressors and race/ethnic differences in hypertension prevalence (the Multi-Ethnic Study of Atherosclerosis). Am J Hypertens. 2011;24(2):187–93. https://doi.org/10.1038/ajh.2010.200.
107. Erbetta K, Almeida J, Waldman MR. Racial, ethnic and nativity inequalities in gestational diabetes mellitus: The role of racial discrimination. SSM Popul Health. 2022;19:101176. https://doi.org/10.1016/j.ssmph.2022.101176.
108. Gaston SA, Atere-Roberts J, Ward J, Slopen NB, Forde AT, Sandler DP, Williams DR, Jackson CL. Experiences with everyday and major forms of racial/ethnic discrimination and type 2 diabetes risk among White, Black, and Hispanic/Latina Women: Findings from the Sister Study. Am J Epidemiol. 2021;190(12):2552–62. https://doi.org/10.1093/aje/kwab189.
109. Kamody RC, Grilo CM, Vásquez E, Udo T. Diabetes prevalence among diverse Hispanic populations: Considering nativity, ethnic discrimination, acculturation, and BMI. Eat Weight Disord. 2021;26(8):2673–82. https://doi.org/10.1007/s40519-021-01138-z.
110. Arriola KJ, Lewis TT, Pearce B, Cobb J, Weldon B, Valentin MIZ, Lea J, Vaccarino V. A randomized trial of race-related stress among African Americans with chronic kidney disease. Psychoneuroendocrinology. 2021;131:105339. https://doi.org/10.1016/j.psyneuen.2021.105339.
111. Sladek MR, Castro SA, Doane LD. Ethnic-racial discrimination experiences predict Latinx adolescents' physiological stress processes across college transition. Psychoneuroendocrinology. 2021;128:105212. https://doi.org/10.1016/j.psyneuen.2021.105212.
112. Forde AT, Lewis TT, Kershaw KN, Bellamy SL, Diez Roux AV. Perceived discrimination and hypertension risk among participants in the Multi-Ethnic Study of Atherosclerosis. J Am Heart Assoc. 2021;10(5):e019541. https://doi.org/10.1161/JAHA.120.019541.
113. Hagiwara N, Green TL, Moreno O, Smith D, Corona R. Ethnic discrimination and weight outcomes among Latinx emerging adults: Examinations of an individual-level mediator and cultural moderators. Cultur Divers Ethnic Minor Psychol. 2021;27(2):189–200. https://doi.org/10.1037/cdp0000336.
114. Manns-James L, Anthony MK, Neal-Barnett A. Racial discrimination, racial Identity, and obesity in collegiate African American women. J Racial Ethn Health Disparities. 2021;8(5):1217–31. https://doi.org/10.1007/s40615-020-00880-x.
115. Barr AB, Simons RL, Beach SRH, Simons LG. Racial discrimination and health among two generations of African American couples. Soc Sci Med. 2022;296:114768. https://doi.org/10.1016/j.socscimed.2022.114768.
116. Cuevas AG, Ho T, Rodgers J, DeNufrio D, Alley L, Allen J, Williams DR. Developmental timing of initial racial discrimination exposure is associated with cardiovascular health conditions in adulthood. Ethn Health. 2021;26(7):949–62. https://doi.org/10.1080/13557858.2019.1613517.
117. Turkson-Ocran RN, Szanton SL, Cooper LA, et al. Discrimination Is associated with elevated cardiovascular disease risk among African immigrants in the African Immigrant Health Study. Ethn Dis. 2020;30(4):651–60. https://doi.org/10.18865/ed.30.4.651.
118. Guyll M, Matthews KA, Bromberger JT. Discrimination and unfair treatment: Relationship to cardiovascular reactivity among African American and European American women. Health Psychol. 2001;20(5):315–25. https://doi.org/10.1037//0278-6133.20.5.315.
119. Ayotte BJ, Hausmann LR, Whittle J, Kressin NR. The relationship between perceived discrimination and coronary artery obstruction. Am Heart J. 2012;163(4):677–83. https://doi.org/10.1016/j.ahj.2012.01.006.
120. Lewis TT, Lampert R, Charles D, Katz S. Expectations of racism and carotid intima-media thickness in African American women. Psychosom Med. 2019;81(8):759–68. https://doi.org/10.1097/PSY.0000000000000684.
121. Gee GC, Ro A, Gavin A, Takeuchi DT. Disentangling the effects of racial and weight discrimination on body mass index and obesity among Asian Americans. Am J Public Health. 2008;98(3):493–500. https://doi.org/10.2105/AJPH.2007.114025.
122. Longmire-Avital B, McQueen C. Exploring a relationship between race-related stress and emotional eating for collegiate Black American women. Women Health. 2019;59(3):240–51. https://doi.org/10.1080/03630242.2018.1478361.
123. Albert MA, Ravenell J, Glynn RJ, Khera A, Halevy N, de Lemos JA. Cardiovascular risk indicators and perceived race/ethnic discrimination in the Dallas Heart Study. Am Heart J. 2008;156(6):1103–9. https://doi.org/10.1016/j.ahj.2008.07.027.
124. Barksdale DJ, Farrug ER, Harkness K. Racial discrimination and blood pressure: Perceptions, emotions, and behaviors of Black American adults. Issues Ment Health Nurs. 2009;30(2):104–11. https://doi.org/10.1080/01612840802597879.
125. Beatty DL, Matthews KA, Bromberger JT, Brown C. Everyday discrimination prospectively predicts inflammation across 7-years in racially diverse midlife women: Study of Women's

Health Across the Nation. J Soc Issues. 2014;70(2):298–314. https://doi.org/10.1111/josi.12061.
126. Beatty Moody DL, Chang Y-F, Pantesco EJ, Darden TM, Lewis TT, Brown C, et al. Everyday discrimination prospectively predicts blood pressure across 10 years in racially/ethnically diverse midlife women: Study of Women's Health Across the Nation. Ann Behav Med. 2019;53(7):608–20. https://doi.org/10.1093/abm/kay069.
127. Brown C, Matthews KA, Bromberger JT, Chang Y. The relation between perceived unfair treatment and blood pressure in a racially/ethnically diverse sample of women. Am J Epidemiol. 2006;164(3):257–62. https://doi.org/10.1093/aje/kwj196.
128. Cobb RJ, Thorpe J, Roland J, Norris KC. Everyday discrimination and kidney function among older adults: Evidence from the Health and Retirement Study. J Gerontol A Biol Sci Med Sci. 2020;75(3):517–21. https://doi.org/10.1093/gerona/glz294.
129. Davis SK, Liu Y, Quarells RC, Din-Dzietharn R, Group MAHDS. Stress-related racial discrimination and hypertension likelihood in a population-based sample of African Americans: the Metro Atlanta heart disease study. Ethn Dis. 2005;15(4):585–93.
130. Dunlay SM, Lippmann SJ, Greiner MA, O'Brien EC, Chamberlain AM, Mentz RJ, et al. Perceived discrimination and cardiovascular outcomes in older African Americans: Insights from the Jackson Heart Study. Mayo Clin Proc. 2017;92(5):699–709. https://doi.org/10.1016/j.mayocp.2017.01.024.
131. Everson-Rose SA, Lutsey PL, Roetker NS, Lewis TT, Kershaw KN, Alonso A, et al. Perceived discrimination and incident cardiovascular events: The Multi-Ethnic Study of Atherosclerosis. Am J Epidemiol. 2015;182(3):225–34. https://doi.org/10.1093/aje/kwv035.
132. Fox RS, Carnethon MR, Gallo LC, Wiley JF, Isasi CR, Daviglus ML, et al. Perceived discrimination and cardiometabolic risk among US Hispanics/Latinos in the HCHS/SOL Sociocultural Ancillary Study. J Behav Med. 2019;26(4):331–42. https://doi.org/10.1007/s12529-019-09782-7.
133. Gabriel AC, Bell CN, Bowie JV, Hines AL, LaVeist TA, Thorpe RJ Jr. The association between perceived racial discrimination and hypertension in a low-income, racially integrated urban community. Fam Community Health. 2020;43(2):93–9. https://doi.org/10.1097/FCH.0000000000000254.
134. Johnson P, Risica PM, Gans KM, Kirtania U, Kumanyika SK. Association of perceived racial discrimination with eating behaviors and obesity among participants of the SisterTalk study. J Natl Black Nurses Assoc. 2012;23(1):34–40.
135. Krieger N, Waterman PD, Kosheleva A, Chen JT, Smith KW, Carney DR, et al. Racial discrimination & cardiovascular disease risk: My body my story study of 1005 US-born Black and White community health center participants (US). PloS One. 2013;8(10):e77174. https://doi.org/10.1371/journal.pone.0077174.
136. Lunyera J, Davenport CA, Bhavsar NA, Sims M, Scialla J, Pendergast J, et al. Nondepressive psychosocial factors and CKD outcomes in Black Americans. Clin J Am Soc Nephrol. 2018;13(2):213–22. https://doi.org/10.2215/CJN.06430617.
137. MacGregor C, Freedman A, Keenan-Devlin L, Grobman W, Wadhwa P, Simhan HN, et al. Maternal perceived discrimination and association with gestational diabetes. Am J Obstet Gynecol MFM. 2020;2(4):100222. https://doi.org/10.1016/j.ajogmf.2020.100222.
138. Matthews KA, Salomon K, Kenyon K, Zhou F. Unfair treatment, discrimination, and ambulatory blood pressure in Black and White adolescents. Health Psychol. 2005;24(3):258–65. https://doi.org/10.1037/0278-6133.24.3.258.
139. Mayne SL, Loizzo L, Bancks MP, Carnethon MR, Barber S, Gordon-Larsen P, et al. Racial residential segregation, racial discrimination, and diabetes: The coronary artery risk development in young adults study. Health Place. 2020;62:102286. https://doi.org/10.1016/j.healthplace.2020.102286.
140. Nadimpalli SB, Dulin-Keita A, Salas C, Kanaya AM, Kandula NR. Associations between discrimination and cardiovascular health among Asian Indians in the United States. J Immigr Minor Health. 2016;18(6):1284–91. https://doi.org/10.1007/s10903-016-0413-3.
141. Peters RM. Racism and hypertension among African Americans. West J Nurs Res. 2004;26(6):612–31. https://doi.org/10.1177/0193945904265816.
142. Peters RM. The relationship of racism, chronic stress emotions, and blood pressure. J Nurs Scholarsh. 2006;38(3):234–40. https://doi.org/10.1111/j.1547-5069.2006.00108.x.
143. Pointer MA, Livingston JN, Yancey S, McClelland MK, Bukoski RD. Psychosocial factors contribute to resting blood pressure in African Americans. Ethn Dis. 2008;18(3):289–93.
144. Reynolds DB, Walker RJ, Campbell JA, Egede LE. Differential effect of race, education, gender, and language discrimination on glycemic control in adults with type 2 diabetes. Diabetes Technol Ther. 2015;17(4):243–7. https://doi.org/10.1089/dia.2014.0285.
145. Krieger N, Carney D, Lancaster K, Waterman PD, Kosheleva A, Banaji M. Combining explicit and implicit measures of racial discrimination in health research. Am J Public Health. 2010;100(8):1485–92. https://doi.org/10.2105/AJPH.2009.159517.
146. Saban KL, Mathews HL, Bryant FB, Tell D, Joyce C, DeVon HA, et al. Perceived discrimination is associated with the inflammatory response to acute laboratory stress in women at risk for cardiovascular disease. Brain Behav Immun. 2018;73:625–32. https://doi.org/10.1016/j.bbi.2018.07.010.
147. Smart Richman L, Pek J, Pascoe E, Bauer DJ. The effects of perceived discrimination on ambulatory blood pressure and affective responses to interpersonal stress modeled over 24 hours. Health Psychol. 2010;29(4):403–11. https://doi.org/10.1037/a0019045.
148 Stepanikova I, Baker EH, Simoni ZR, Zhu A, Rutland SB, Sims M, et al. The role of perceived discrimination in obesity among African Americans. Am J Prev Med. 2017;52(1S1):S77–85. https://doi.org/10.1016/j.amepre.2016.07.034.
149. Victor RG, Leonard D, Hess P, Bhat DG, Jones J, Vaeth PAC, et al. Factors associated with hypertension awareness, treatment, and control in Dallas County. Texas Arch Intern Med. 2008;168(12):1285–93. https://doi.org/10.1001/archinte.168.12.1285.
150. Wright ML, Lim S, Sales A, Rajagopal S, Nzegwu D, Crusto CA, et al. The influence of discrimination and coping style on blood pressure among Black/African American women in the InterGEN study. Health Equity. 2020;4(1):272–9. https://doi.org/10.1089/heq.2019.0122.
151. Shin CN, Soltero E, Mama SK, Sunseri C, Lee RE. Association of discrimination and stress with cardiometabolic risk factors in ethnic minority women. Clin Nurs Res. 2017;26(6):694–712. https://doi.org/10.1177/1054773816669448.
152. Michaels EK, Reeves AN, Thomas MD, Price MM, Hasson RE, Chae DH, Allen AM. Everyday racial discrimination and hypertension among midlife African American women: Disentangling the role of active coping dispositions versus active coping behaviors. Int J Environ Res Public Health. 2019;16(23):4759. https://doi.org/10.3390/ijerph16234759.

153. Nguyen AW, Hamler TC, Cobb RJ. Discrimination and chronic kidney disease among Caribbean Blacks: The effects of immigration and social status. Race Soc Probl. 2018;10(3):248–58. https://doi.org/10.1007/s12552-018-9234-4.
154. Hunte HE, Williams DR. The association between perceived discrimination and obesity in a population-based multiracial and multiethnic adult sample. Am J Public Health. 2009;99(7):1285–92. https://doi.org/10.2105/AJPH.2007.
155. Neblett EW Jr, Carter SE. The protective role of racial identity and Africentric worldview in the association between racial discrimination and blood pressure. Psychosom Med. 2012;74(5):509–16. https://doi.org/10.1097/PSY.0b013e3182583a50.
156. United States Census Bureau . Racial and ethnic diversity in the United States: 2010 Census and 2020 Census. 2021. https://www.census.gov/library/visualizations/interactive/racial-and-ethnic-diversity-in-the-united-states-2010-and-20-census.html. Accessed December 29, 21.
157. Braveman PA, Arkin E, Proctor D, Kauh T, Holm N. Systemic and structural racism: Definitions, examples, health damages, and approaches to dismantling. Health Aff (Millwood). 2022;41(2):171–8. https://doi.org/10.1377/hlthaff.2021.01394.