



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 two-fold: 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,

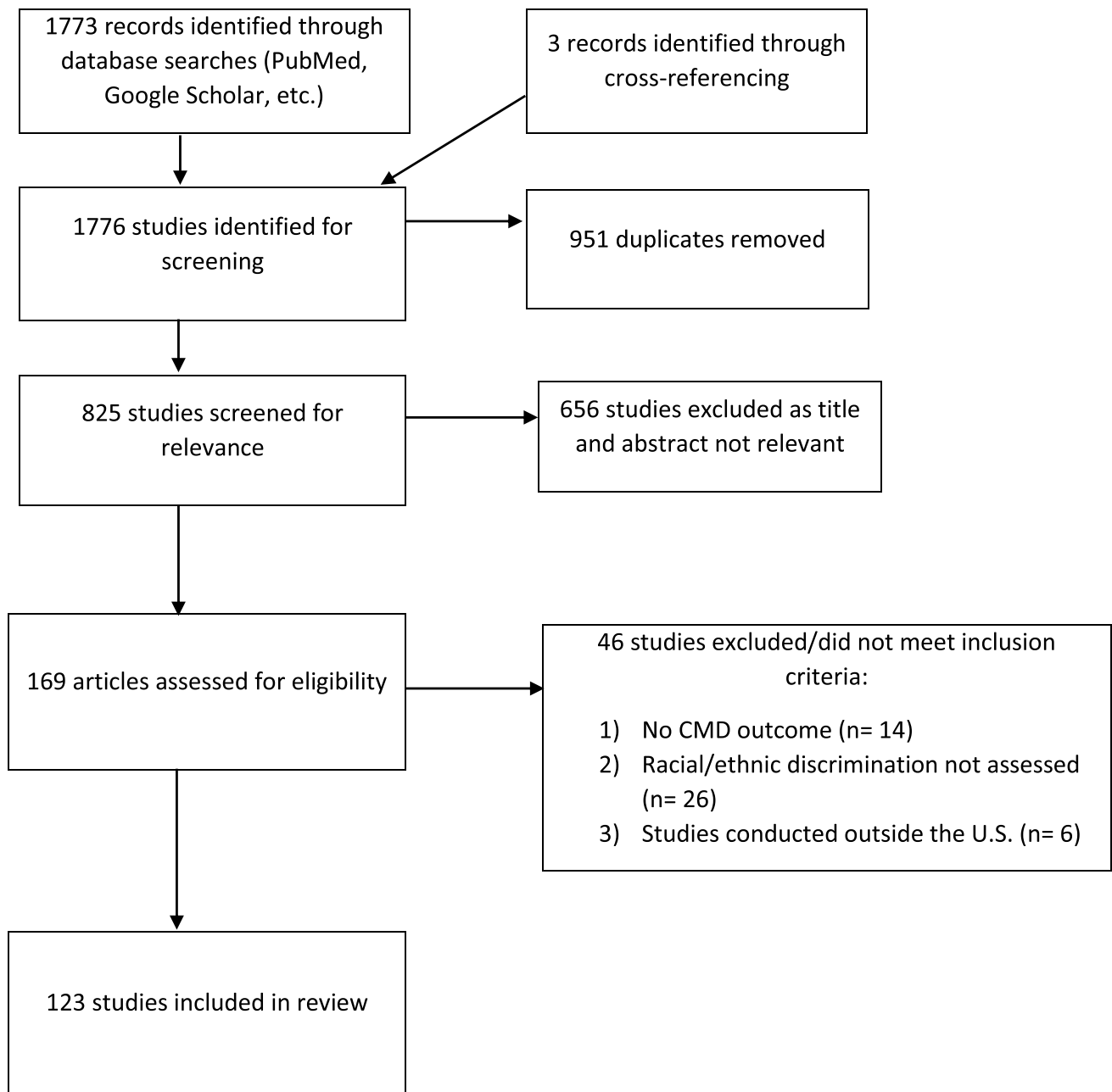


Fig. 1 Flow chart of article selection process

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 participants, 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	$\alpha 1$ and β 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	<i>N</i> = 4,086 adults, Black (<i>n</i> = 1,974), White (<i>n</i> = 2,112) men (<i>n</i> = 1,837), women (<i>n</i> = 2,249)	SBP and DBP	HTN	Experiences of Discrimination Scale	Yes
25 Clark 2000	Cross-sectional	<i>N</i> = 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	<i>N</i> = 69 AA adults, men (<i>n</i> = 30) and women (<i>n</i> = 39), aged 25–44	SBP and DBP	HTN	Perceived Racism Scale	Yes
27 Din-Dzethiam et al. 2004	Cross-sectional	<i>N</i> = 356 adults, AA men (<i>n</i> = 160) and women (<i>n</i> = 196)	SBP and DBP	HTN	Self-reported measure	Yes
28 Peters 2004	Cross-sectional	<i>N</i> = 162 AA adults, men (<i>n</i> = 29), women (<i>n</i> = 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	<i>N</i> = 356 AA adults, men (<i>n</i> = 160), women (<i>n</i> = 196)	SBP and DBP	HTN	Adaptation of Perceived Racism Scale and Index of Race-Related Stress	No
30 Matthews et al. 2005	Cross-sectional	<i>N</i> = 212 adolescents, Black (<i>n</i> = 106), White (<i>n</i> = 106), men (<i>n</i> = 105), women (<i>n</i> = 107)	ABP and Heart Rate	HTN	Everyday Discrimination Scale	No
31 Brown et al. 2006	Cross-sectional	<i>N</i> = 3,300 [AA (<i>n</i> = 934), Caucasian (<i>n</i> = 1,549), Chinese (<i>n</i> = 250), Hispanic (<i>n</i> = 286), and Japanese (<i>n</i> = 281) women]	SBP and DBP	HTN	Everyday Discrimination Scale	No
32 Peters 2006	Cross-sectional	<i>N</i> = 162 AA adults, men (<i>n</i> = 29), women (<i>n</i> = 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 (<i>n</i> = 78), Black immigrants (<i>n</i> = 112), Latino immigrants (<i>n</i> = 476)	SBP and DBP	HTN	The Reactions to Race Module	Yes
34 Hill et al. 2007	Cross-sectional	N = 40 AA college students, men (<i>n</i> = 19) women (<i>n</i> = 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 (<i>n</i> = 63), women (<i>n</i> = 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 (<i>n</i> = 393) and women (<i>n</i> = 717), aged 25–50	SBP and DBP	HTN	Everyday Discrimination Scale	Yes, AA women only
37 Salomon and Jaguszyn 2008	Cross-sectional	N = 70 college undergraduates, White (<i>n</i> = 28), Black (<i>n</i> = 24), and Latino (<i>n</i> = 18), men (<i>n</i> = 20) and women (<i>n</i> = 50)	SBP, DBP and HR reactivity	HTN	Perceived Ethnic Discrimination Questionnaire	Yes
38 Singleton et al. 2008	Cross-sectional	N = 52 Black adults, men (<i>n</i> = 11) and women (<i>n</i> = 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 (<i>n</i> = 1,194), White (<i>n</i> = 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 (<i>n</i> = 147), men (<i>n</i> = 64)]	Mean SBP and DBP	HTN	Perceived Racism Scale	No
41 Lewis et al. 2009	Cross-sectional	N = 4,694, AA (<i>n</i> = 2,826), White (<i>n</i> = 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 (<i>n</i> = 46), women (<i>n</i> = 86)	SBP and DBP	HTN	Perceived Discrimination Scale	Yes
43 Smart Richman et al. 2010	Cross-sectional	N = 62 adults, Black (<i>n</i> = 31) and White (<i>n</i> = 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 (<i>n</i> = 442) and White (<i>n</i> = 1018)	Self-reported HTN	HTN	Experiences of Discrimination Scale	No
45 Mujahid et al. 2011	Cross-sectional	N = 2,679 adults, AA (<i>n</i> = 1,159), Hispanic (<i>n</i> = 415), White (<i>n</i> = 1,105) men (<i>n</i> = 1,236) and women (<i>n</i> = 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 (<i>n</i> = 42), women (<i>n</i> = 104)	SBP, DBP, Salivary Cortisol	HTN	Oppression Questionnaire	Yes
47 Klimentidis et al. 2012	Cross-sectional	N = 294 children aged 7–12, AA (<i>n</i> = 96), EA (<i>n</i> = 114), Hispanic American (<i>n</i> = 78), biracial (<i>n</i> = 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 (<i>n</i> = 60), women (<i>n</i> = 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 (<i>n</i> = 3,123), men (<i>n</i> = 1816)	SBP and DBP	HTN	Jackson Heart Study Discrimination Instrument	Yes
50 Gregoski et al. 2013	Cross-sectional	N = 352 young adults, AA (<i>n</i> = 175), White (<i>n</i> = 177)	Plasma endothelin 1, ABP	Nocturnal dipping/ HTN	Everyday Discrimination Scale	Yes
51 Kreiger et al. 2013	Cross-sectional	N = 1,005 adults, Black (<i>n</i> = 504), White (<i>n</i> = 501), men (<i>n</i> = 340), women (<i>n</i> = 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 (<i>n</i> = 39), White (<i>n</i> = 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 (<i>n</i> = 318) and Latino(a) (<i>n</i> = 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, IL6, IL8, IL10, 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	<i>N</i> = 2,180 (Black, White, Hispanic, Chinese, and Japanese)	SBP and DBP	HTN	Everyday Discrimination Scale	No
100 Forde et al. 2020	Longitudinal	<i>N</i> = 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	<i>N</i> = 3,297 adults aged 45–84, White (<i>n</i> = 1454), Black (<i>n</i> = 626), Hispanic (<i>n</i> = 743), Chinese (<i>n</i> = 474)	SBP, DBP	HTN	Everyday Discrimination Scale and Lifetime Discrimination Scale	Yes, for Black participants
102 Bacon et al. 2017	Longitudinal	<i>N</i> = 45,781 (AA women aged 21–69)	BMI	Type 2 Diabetes	Everyday Discrimination Scale	Yes
103 Whitaker et al. 2017	Longitudinal	<i>N</i> = 5,310 adults, AA (<i>n</i> = 1,300), White (<i>n</i> = 2,266), Hispanic (<i>n</i> = 1,103), Chinese (<i>n</i> = 641), men (<i>n</i> = 2,484) and women (<i>n</i> = 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	<i>N</i> = 2,175 Black adults	HbA1c, FBG, oral tolerance test	Diabetes	Experiences of Discrimination scale	No
105 Gaston et al. 2021	Longitudinal	<i>N</i> = 33,833 women, NH White (<i>n</i> = 30,409), NH Black (<i>n</i> = 2,435), Hispanic/Latina (<i>n</i> = 989), mean age 54.9	Self-report	Type 2 Diabetes	Everyday Discrimination Scale	Yes, for major discrimination only
106 Cozier et al. 2014	Longitudinal	<i>N</i> = 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	<i>N</i> = 3,336, [Black women <i>n</i> = 901, Black men <i>n</i> = 614, White women <i>n</i> = 958, and White men <i>n</i> = 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 Gyll 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 amylose, 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 (<i>n</i> = 27), men (<i>n</i> = 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 (<i>n</i> = 31), women (<i>n</i> = 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 (<i>n</i> = 21), women (<i>n</i> = 31)	IL6, SBP, DBP	CKD	Race-Based Rejection Sensitivity Questionnaire	Yes
123 Tull and Chambers 2001	Case-control	N = 82 Black adults, men (<i>n</i> = 37) and women (<i>n</i> = 45), mean age 59	Fasting blood glucose	Type 2 Diabetes	Nadanolization 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, Tri-glycerides	2		5		0		0		5
IL1, IL6, IL8, IL10, 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 β 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.

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