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REGULAR ARTICLE

Everyday Discrimination Prospectively Predicts Blood Pressure Across 10 Years in Racially/Ethnically Diverse Midlife Women: Study of Women's Health Across the Nation

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Abstract

Background Interpersonal discrimination is linked to greater risk for cardiovascular disease (CVD) and this association varies by race/ethnicity.

Purpose To examine whether exposure to everyday discrimination prospectively predicts elevated blood pressure (BP), whether this association differs by race/ethnicity, and is mediated by adiposity indices.

Methods Using data for 2,180 self-identified White, Black, Chinese, Japanese, and Hispanic participants from the Study of Women's Health Across the Nation, we examined associations among exposure to (higher vs. lower) everyday discrimination at baseline and BP and hypertension (HTN; systolic blood pressure [SBP] ≥ 140 mmHg; diastolic blood pressure [DBP] ≥ 90 mmHg; or self-reported HTN medication use) risk over a 10 year period. Additionally, we used the bootstrap method to assess repeated, time-varying markers of central and overall adiposity (waist circumference and body mass index [BMI] (kg/m^2), respectively) as potential mediators.

Results Exposure to everyday discrimination predicted increases in SBP and DBP over time, even after adjusting for known demographic, behavioral, or medical risk factors. However, greater waist circumference or BMI (examined separately) mediated these observations. Notably, there were no racial/ethnic differences in the observed association and HTN risk was not predicted.

Conclusions The current findings suggest that everyday discrimination may contribute to elevated BP over time in U.S. women, in part, through increased adiposity. These findings demonstrate the complexity of the linkage of discrimination to CVD risk and raise the need to closely examine biobehavioral pathways that may serve as potential mediators.

Keywords Blood pressure • Racial/ethnic diversity • Longitudinal • Everyday discrimination • Waist circumference • Body mass index

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Introduction

Elevated blood pressure (BP) is a precursor to hypertension (HTN) onset. HTN, a primary risk factor for cardiovascular disease (CVD) and related mortality [1], varies by gender across the life course, with older women having higher rates of HTN than older men [2]. In the USA, HTN accounts for one in five deaths in women [3] and is a primary risk factor in the incidence of myocardial infarction, stroke, and end-stage renal disease in this group. Although one in four U.S. women have HTN [4], there are disparities in these rates by race/ethnicity. For instance, Black women tend to have the highest prevalence of HTN (42.9%) compared with Hispanic women

(24.7%; Refs. 5 and 6), White women (21.9%), and Asian women (20.2%) [5, 7]. As such, racial disparities in HTN are a major public health issue and have been identified in the Healthy People 2020 national objectives for targeted reduction [8]. Furthermore, traditional risk factors such as family history, obesity, and cigarette smoking do not fully explain the prevalence of elevated BP or HTN [9].

Research has demonstrated that chronic exposure to psychosocial stressors may contribute to elevated BP and HTN [10]. A preponderance of the work explicating psychosocial stressors has focused on bias experienced in one-on-one interactions, often referred to as interpersonal discrimination. Interpersonal discrimination is commonly assessed via one of two constructs: racial discrimination or everyday discrimination. Racial discrimination may be reflected in the "behaviors and acts intended to denigrate an individual or groups because of phenotypical characteristics, racial or ethnic group affiliation" (p. 805, Ref. 11), whereas everyday discrimination is characterized by interpersonal exchanges in which subtle disrespect, or minor slights in the form of unfair treatment or bias, is conveyed and arises for any reason (i.e., not exclusive to race/ethnicity). A comprehensive body of literature demonstrates that everyday discrimination confers poor health [12, 13] among racial/ethnic minorities, and emerging research suggests a similar pattern in nonminority racial/ethnic groups as well.

Specifically, everyday discrimination has been found to increase CVD risk (e.g., obesity, BP, inflammation, sleep disturbance, and coronary artery calcification) in both racial/ethnic minorities and nonminority racial/ethnic groups (e.g., see Refs. 14–18). Although the bulk of this work has been conducted in Blacks, there is evidence for similar associations in other racial/ethnic groups. For instance, in cross-sectional studies, racial discrimination has been linked to greater CVD disease risk via nondipping ambulatory BP in non-White Hispanics (e.g., Ref. 19), and interpersonal discrimination has been linked to cardiovascular risk factors (i.e., obesity and smoking) and self-reported CVD (e.g., HTN, myocardial infarction, and coronary heart disease) in ethnically diverse Asian American samples (including Chinese and/or Japanese Americans; Refs. 20–23). In Whites [24], greater everyday discrimination has been associated with excess body fat accumulation. Thus, it is plausible that although racial/ethnic minorities, particularly Blacks, would experience a more pronounced linkage of discrimination to health given the sociohistorical context of race/ethnicity in the USA, a similar pattern could also emerge in other racial/ethnic groups who report experiences of unfair treatment. However, there is no research that prospectively examines these linkages with regard to BP and HTN in a racially/ethnically diverse sample of U.S. women, nor whether these associations differ as a function of race/ethnicity.

Recent reviews [12, 25], including a meta-analysis [12] on interpersonal discrimination and BP, indicate that the linkage of interpersonal discrimination to resting BP is inconsistent and weak. However, most studies have not prospectively examined this association, and none have examined mediational pathways that may account for or attenuate this linkage. For instance, in more than 4,900 Blacks participating in the Jackson Heart Study, the largest investigation of CVD in Blacks, Sims et al. [26] reported null findings for the relation of everyday discrimination to HTN prevalence in a cross-sectional analysis, but those reporting the highest levels of lifetime discrimination (e.g., getting a job, housing, or services) across various domains had the highest prevalence of HTN. As suggested by Sims et al. [26], perhaps the null findings were observed because everyday discrimination reflects experiences that are frequent and chronic, but relatively minute, leading to a slower emergence of their physiological impact. Thus, tracking BP or HTN longitudinally may be necessary in order to capture the effects of everyday discrimination which may accumulate gradually.

In the only longitudinal assessment of interpersonal discrimination and BP, based on the Black Women's Health Study (BWHS), Cozier et al. [27] reported null findings for the direct relation of everyday discrimination to HTN over a 4 year period. However, as noted by the authors [27], the failure to observe a finding may have been due to the BHWS' use of only a subset of questions assessing these experiences from a well-established and reliable measure. Additionally, as previously suggested [26], owing to the subtler nature of this particular form of interpersonal discrimination, it is unclear if an association would have been evidenced within a longer BP follow-up period. It is also possible that cases were underreported due to lack of participant awareness about their HTN status [28] since BP levels were not assessed by study staff, and HTN was only determined via self-report. The prospective examination of everyday discrimination and measured BP may provide greater understanding of these linkages and the potential pathways between them.

The linkage of everyday discrimination to BP/HTN certainly unfolds within a biopsychosocial context [29] for which the contribution of potential biological explanatory mechanisms is poorly understood. In this regard, weight or adiposity may be a particularly critical biological intermediary. Experiences of interpersonal discrimination have been shown to predict increases in adiposity over time [30] and relatedly, markers of adiposity are linked to the development of higher BP and HTN [31]. Furthermore, evidence from prior studies of interpersonal discrimination and CVD risk factors, including BP, suggests a potential mediating role of adiposity [26, 32]. Thus, adiposity may be important to consider when

investigating the relationship between interpersonal discrimination and HTN.

Waist circumference and body mass index (BMI) are two well-established markers of central adiposity and overall adiposity, respectively. A recent review [30] of 10 longitudinal studies demonstrated that interpersonal experiences of discrimination (including everyday discrimination) were consistently associated with increases in BMI, and just under half of the studies demonstrated relationships with waist circumference. These associations were more consistent in women than men. Although the longitudinal studies examining everyday discrimination have primarily included Black and/or White participants, similar findings have also emerged in cross-sectional studies with Hispanic and Asian women [22, 33, 34]. Altogether, these studies demonstrate that the relation of interpersonal discrimination to weight may be especially pronounced in women and, thus, particularly important for understanding disease endpoints observed in this group. It is posited that interpersonal discrimination may influence weight directly through stress-induced, physiological dysregulation of the hypothalamic–pituitary–adrenal axis and indirectly through behavior-based responses such as stress-induced food consumption [35, 36, 37].

In turn, waist circumference and BMI are prospectively implicated in the development of HTN [38], partly through an increased cardiac response [38]. Although the literature generally demonstrates that greater waist circumference and BMI are predictive of HTN, it remains unclear which of the two is the stronger or more reliable predictor, especially across diverse racial/ethnic groups (e.g., Ref. 39). For instance, some studies show that waist circumference is an independent, and/or stronger, predictor of incident HTN compared with BMI [40–43], whereas other studies report that waist circumference and BMI hold similar prognostic value [37, 44–46]. Furthermore, there are established weight differences among women across racial/ethnic groups. Across two survey cycles of the National Health and Nutrition Survey (NHANES), a nationally representative sample of U.S. adults ≥ 20 years of age, including ≈10,000 racially/ethnically diverse women [47–49], waist circumference and BMI were highest in Black women followed by Hispanic, White, and Asian American women, respectively. Perhaps race/ethnicity–related patterns in these indices of weight partially reflect uneven exposure to psychosocial stressors and, in turn, contribute to uneven rates of CVD burden. Thus, empirical examination of weight as a potential mediating pathway may allow greater clarity on the causal biological mechanisms linking interpersonal discrimination to BP and HTN and potentially offer a point of intervention in the discrimination-CVD link.

Current Study

To address the inconsistencies in previous studies and examine a potential mediating pathway between interpersonal discrimination and BP, we utilized existing data from the Study of Women's Health Across the Nation (SWAN). SWAN was designed as an observational, prospective, multisite, and longitudinal study of more than 3,100 healthy, racially/ethnically diverse women that focuses on the biological and psychosocial changes that transpire across the menopausal transition. As such, SWAN included measures of everyday discrimination, as well as annual assessments of waist circumference, BMI, and BP, which were the focus of the current study. A previous cross-sectional examination of everyday discrimination and BP in the SWAN study observed no association at study entry [50]. In the current paper, we extend these previous SWAN findings by examining the following: (a) whether everyday discrimination prospectively predicts elevated BP and HTN risk over a 10 year follow-up period; (b) whether these associations are consistent across racial/ethnic minority and nonminority racial/ethnic groups, specifically Black, White, Chinese, Hispanic, and Japanese women; and (c) whether adiposity markers, specifically, waist circumference and BMI measured annually over the follow-up, mediate these associations. SWAN is an optimal sample in which to investigate the association of everyday discrimination and high BP in mid-life because (a) it has annually observed participants for over a decade enabling thorough characterization of BP and related behavioral and health changes, (b) 78 per cent of participants have completed most visits since study initiation, and (c) this sample represents one of the largest and most racially/ethnically diverse samples of women followed in the USA.

Methods

Participants and Procedure

This analysis used data from the baseline and the first 10 annual follow-up visits of the SWAN cohort. The SWAN study was conducted across seven clinical sites. Specifically, each site recruited approximately 450 participants, which included White women and women of one other predetermined racial group; Blacks in Pittsburgh, Pennsylvania; Boston, Massachusetts; Chicago, Illinois, and the Detroit area, Michigan; Chinese in Oakland, California; Hispanics in Newark, New Jersey; and Japanese in Los Angeles, California. Approximately 50 per cent (n = 3,302) of women recruited were enrolled in the SWAN longitudinal cohort study. Significant racial/ethnic differences (p < .0001) were observed in entry

acceptance rates—Chinese (69.1%), Japanese (63.3%), and Black (55%) were more likely to enter the study compared with White (48.4%) and Hispanic (35.7%) women. Furthermore, eligible women who were less likely to enter the cohort study were less educated, more likely to smoke, and/or have greater difficulty paying for basics. Further information is detailed in a prior report [51].

Eligibility criteria for admission to the SWAN cohort study included being between the ages of 42–52, a primary racial/ethnic self-identification as White, Black/African American (referred to herein as Black), Chinese, Japanese, or Hispanic, being either early perimenopausal or premenopausal, having an intact uterus, and having had at least one menstrual period and no use of reproductive hormones in the previous 3 months. To determine eligibility for entry to the SWAN study, health history, reproductive, demographic, and lifestyle data were collected during screening interviews conducted between November 1995 and October 1997. Self-report was used to assess parental history of HTN at baseline. Current smoking status was also assessed at baseline and at each follow-up visit. Research assistants with bilingual backgrounds were available to aid participants with language, literacy, or vision difficulties. Multiple strategies were used for sample recruitment, including community census and registered voters' data, random digit dialing, and "snowballing." Further details of the study's methodology have been published elsewhere [52].

The current analyses are based on a subset of 2,180 women from the longitudinal cohort of 3,302. We excluded 1,122 women from the current analyses. Specifically, 491 were excluded because they were taking BP medications, insulin or oral hypoglycemics at baseline, or had a history of stroke or heart attack at baseline; 228 were missing discrimination data at baseline or had no follow-up discrimination data; 25 were missing baseline BP data or had no follow-up BP data; 355 were missing education or history of HTN data; 23 were missing BMI or age data at baseline; and 3 were missing waist circumference data. Thus, if the analyses specific to waist circumference 2,177 women were included, otherwise all analyses include 2,180 women (i.e., ≈66% of the women in the longitudinal cohort).

Measures

Demographics

Information on educational attainment, income, menopausal status, immigrant status, waist circumference, and body mass index (BMI) was obtained at baseline. At baseline, education was categorized as < and ≥ a college degree and annual income as < and ≥ US$50,000, and due to SWAN study recruitment criteria, participants were either premenopausal or early perimenopausal (45 women were missing menopausal status data at baseline). At each follow-up, menopausal status was assessed. Five menopausal categories were used as follows: premenopause, early perimenopause, late perimenopause, surgical/postmenopause, and indeterminate menopause (e.g., could not be determined due to use of hormones before they were postmenopausal).

Everyday discrimination exposure

The primary predictor, everyday discrimination exposure, was assessed at baseline using the 9-item Williams' Everyday Discrimination Scale [52]. The measure begins with the following statement: "In your day-to-day life have you had the following experiences?" and sample items include "You are treated with less courtesy than other people," "People act as if they think you are not smart," and "You receive poorer service than other people at restaurants or stores." Of note, the SWAN study protocol adapted this measure to include the following additional item: "People ignore you or act as if you are not there," which has been included in previously published studies (e.g., see Ref. 53). Responses to the 10 items are indicated on a four-point Likert scale (i.e., often, sometimes, rarely, and never). This measure of everyday discrimination has been used widely in the epidemiological literature, with documented internal reliability [14], convergent and divergent validity [53], and stability over time [14]. In a previous paper based on this sample, reports of everyday discrimination were stable across follow-up. As we seek to examine the impact of exposure to everyday discriminatory experiences, following the procedure previously established in cross-sectional and prospective epidemiological studies [18, 50, 54–56], responses were recoded to a binary format (often or sometimes = 1, rarely or never = 0) to assess *high* versus *low or no* exposure. Prior reports employing this approach have demonstrated that exposure is linked to a range of adverse health outcomes (e.g., Refs. 18 and [56–61]).

Blood pressure and hypertension status

The outcome variables included BP and HTN status, both assessed at baseline and at each of the annual follow-up visits. Three consecutive BP measurements were obtained by a trained technician with a random-zero sphygmomanometer and were standardized for cuff size, position, and rest period at baseline and at follow-up visits 1–10. The first measurement was excluded, and the latter two BP readings were averaged for each participant. To ensure quality technician performance and compliance with a standard protocol, all SWAN interviewers were certified before collecting physical measures on participants. HTN status at the follow-up visits was

determined when participants met the following criteria [62]; systolic blood pressure (SBP) ≥ 140 mmHg, or diastolic blood pressure (DBP) ≥ 90 mmHg, or self-reported use of pharmacologic therapy for HTN [50].

Waist circumference and BMI

Waist circumference and BMI were assessed at baseline and at each follow-up visit. Waist circumference was measured to the nearest 0.1 cm following standardized protocols by placement of a tape measure around the narrowest point of the torso. BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). The ICCs for waist circumference and BMI were 0.90 and 0.94, respectively.

Statistical approach

Sample descriptives for demographic and physiologic variables were assessed using means ± SD for continuous variables and (*n*)% for categorical variables. The longitudinal associations between everyday discrimination exposure and BP were assessed using generalized estimating equations (GEEs) with identity link functions. GEE is an extension of the generalized linear model and is used to analyze longitudinal data where multiple observations from the same participant are likely to be correlated. The GEE method, which takes into account the within-subject correlation, uses quasilikelihood estimation to estimate the parameters and is robust to misspecification of the unknown correlation structure. We also tested an interaction term, Race/Ethnicity x Everyday Discrimination Exposure, to determine whether the associations of everyday discrimination exposure with SBP, DBP, and HTN risk differed as a function of race/ethnicity.

All covariates included in the fully adjusted models were selected based on their established relationships with everyday discrimination [12, 50, 63–65] or with the BP endpoints [66–68]. The baseline covariates included study site, race/ethnicity, age, education, and parental history of HTN. The time-varying covariates included visit (time), smoking, menopausal status, new heart attack or stroke, diabetic status, BP medications, and other medications (including anticoagulants, insulin, estrogen, progesterone, birth control pills, and medication for heart irregularities). Both the baseline and time-varying covariates were used in fully adjusted models predicting BP.

The effect of baseline everyday discrimination exposure on the risk of HTN during follow-up was assessed among those free of HTN at baseline. Since the exact time to the first HTN event cannot be observed but was only known to be between two study visits, an interval-censored survival model by Weibull regression was applied to estimate the hazard ratio and its 95% confidence interval. Covariates for the HTN model included baseline (study sites, race/ethnicity, education, parental history of HTN, and baseline age) and time-varying covariates (smoking, diabetes, menopausal status, and medication use). Of note, the HTN model was not adjusted for the BP medication use due to its overlap with the outcome variable.

Across models predicting BP and HTN risk, we tested for waist circumference and BMI change as time-varying mediators, thus capturing changes in these measures over the follow-up period. The indirect effect of the potential mediator, and its 95% confidence interval, was generated by the bootstrap method [69]. Five hundred computer-generated samples were derived from the study population via random selection. The covariates were the same as those outlined above. The bootstrap method was also applied to determine whether time-varying waist circumference and BMI mediated the link of everyday discrimination exposure to HTN risk. Due to evidence that waist circumference may be a better indicator of health risk than BMI (e.g., Ref. 41), we treated waist circumference as the primary mediator, testing these models first. We then repeated all analyses testing BMI as a mediator to determine whether results were similar. Finally, we also examined the interaction of everyday discrimination exposure with waist circumference and BMI to determine whether the effect of discrimination in predicting BP differed by adiposity.

Hispanic women were only recruited at the New Jersey (NJ) site for SWAN, and this site had all but 2 years of BP data available for the current analyses due to a significant delay in follow-up unrelated to the scientific purpose of SWAN (data for visits 7 and 8 were not collected). To determine whether analyses were sensitive to the missing data for the Hispanic women, we performed separate analyses by excluding the NJ site. The results were similar; thus, data from the NJ site were included in all analyses. With regard to overall retention, when the NJ site was not considered, the rate of loss to follow-up across the six remaining sites for the period of the current analyses, dropped from 22.2% to 13.9%. All analyses were conducted using Statistical Analysis System, version 9.4 software (SAS Institute, Inc., Cary, North Carolina). A p value of ≤.05 was used as the significance cutoff.

Sensitivity analyses

It is possible that women with higher waist circumference or higher BMI might report greater everyday discrimination exposure at baseline due to their appearance (e.g., weight). Therefore, we reran the main study models excluding all women who selected physical appearance as the primary reason for the discrimination they experienced (i.e., excluding $n = 116$ in analyses examining waist circumference as

a mediator and excluding n = 112 in analyses examining BMI as a mediator) and examined whether the pattern of results remained similar to the findings in the full sample.

Results

Descriptives

The full sample included 2,180 women, whereas analyses including waist circumference included 2,177 due to incomplete data. Sample characteristics at baseline are reported in Table 1 for the full sample and by the standardized waist circumference cutoff point (i.e., > or ≤ 88 cm; Ref. 70) Hispanic and Black women had the lowest levels of education and income. HTN status, SBP, and DBP were higher in women with a waist circumference greater than 88 cm compared with those with a waist circumference of 88 cm or less. Approximately 50 per cent of the sample reported experiencing everyday discrimination at least "sometimes" or "often" at baseline, and these reports were more frequent among women with waist circumferences greater than 88 cm (Table 1). At baseline, in accordance with NHLBI guidelines on BMI [71], almost half (46.4%) of the sample had at least "normal" weight, whereas 28.1 per cent were "overweight" and 25.5 per cent were considered "obese." In data not shown, Black women had the highest waist circumferences, highest BMIs, and the highest prevalence of hypertensive BP readings at baseline. Black women also reported the highest rates of exposure to everyday discrimination across all racial/ethnic groups in the sample.

Table 1 Baseline characteristics of SWAN participants in the full sample and stratified by waist circumference cutoffs

	Full sample		Waist circumference stratified groups				
			≤88 cm		>88 cm		
	N = 2,180[a]		n = 1,514		n = 663		p Value
Characteristics							
Sociodemographic							
Age (years), M(*SD*)	45.76	2.66	45.73	2.64	45.82	2.69	.47
Education (≥college degree), *n*(%)	1064	48.90%	787	52%	277	41.80%	<.0001
Health status factors							
Menopausal status							
Early perimenopausal, *n*(%)	928	43.47%	620	41.80%	308	47.24%	.02
Premenopausal, *n*(%)[b]	1207	56.53%	863	58.20%	344	52.76%	
Current smoker (yes), *n*(%)	300	14%	193	12.80%	107	16.30%	.03
Waist circumference, M(SD)	83.52	14.52	75.67	6.78	101.45	11.48	<.0001
BMI, M(SD), kg/m^2	27.02	6.48	23.82	3.29	34.38	6.00	<.0001
Diabetic (yes), *n*(%)	38	1.80%	24	1.60%	14	2.1%	.38
Anticoagulant medication (yes), *n*(%)	13	.60	7	.50%	6	.90%	.23
Heart medication (yes), *n*(%)	26	1.20%	18	1.19%	8	1.21%	.98
Family history of HTN (yes), *n*(%)	1483	68.10%	1016	67.11%	467	70.40%	.12
Primary study variables							
Resting blood pressure, M(*SD*)							
SBP, mmHg	114.83	15.3	112.18	14.7	120.9	15.02	<.0001
DBP, mmHg	74.14	9.84	72.94	9.79	76.91	9.42	<.0001
Hypertensive status (yes), *n*(%)[c]	216	9.95%	109	7.22%	107	16.20%	<.0001
Everyday discrimination exposure (yes), *n*(%)[d]	1077	49.50%	680	44.90%	397	59.90%	<.0001

NIH standardized waist circumference cutoff points (i.e., > or ≤ 88 cm) were used.

M mean; *SD* standard deviation; *BMI* body mass index; *SBP* systolic blood pressure; *DBP* diastolic blood pressure.

[a]N varies slightly due to three women missing waist circumference data.

[b]At baseline all women were either premenopausal or early perimenopausal; 45 women were missing baseline menopausal status data.

[c]Hypertensive status at baseline was determined when systolic blood pressure was ≥140 mmHg or diastolic blood pressure was ≥90 mmHg or receiving pharmacologic therapy for hypertension.

[d]Everyday discrimination exposure (yes) was determined when respondents indicated that any type of everyday discrimination occurred at least "sometimes" or "often."

Over the course of follow-up, SBP and DBP increased, on average, by 4.74 mmHg (*SD* = 16.32) and 0.10 mmHg (*SD* = 10.99), respectively. There were 607 (27%) cases of incident HTN reported across the 10 year follow-up period, with 215 (35%), 261 (43%), 44 (7.3%), 28 (4.6%), and 59 (9.7%) among Blacks, Whites, Chinese, Hispanic, and Japanese, respectively. Waist circumference increased by 5.64 cm (*SD* = 7.99) and BMI increased by 1.61 (*SD* = 3.12).

As shown in Table 2, everyday discrimination exposure at baseline was associated with higher waist circumference over the 10 year follow-up in fully adjusted models in the full sample. Race/ethnicity–stratified models demonstrated similar effects with the exception of null findings in the Hispanic (who were missing follow-up data from visits 7 and 8) and Chinese women. Similarly, in fully adjusted models with BMI as the outcome, everyday discrimination exposure at baseline was associated with higher BMI over the follow-up period in the full sample. Race/ethnicity–stratified models demonstrated a pattern of results similar to waist circumference, with null findings in Hispanic and Chinese women.

Everyday Discrimination Exposure, Waist Circumference, BMI, and BP Over Time

Everyday discrimination predicting BP over time

In analyses examining everyday discrimination exposure as a predictor of BP over time, the pattern of results was highly similar in both the full sample (*N* = 2,180) and in participants who had all waist circumference data available (*N* = 2,177; Table 3). Here, we report the results from models including all waist circumference data. After adjusting only for age and time, baseline exposure to everyday discrimination prospectively predicted elevated SBP (2.19; 95% CI: 1.21, 3.16) and DBP (0.99; 95% CI: 0.41, 1.56) over the 10 year follow-up period (Table 3). When fully adjusted for all covariates, exposure to everyday discrimination remained a significant predictor of SBP and DBP. Women who at baseline reported higher exposure (i.e., "often" or "sometimes") to everyday discrimination had SBP 1.25 mmHg higher (95% CI: 0.31, 2.19) and DBP 0.89 mmHg higher (95% CI: 0.32, 1.46) over the 10 year follow-up period than those reporting less exposure after adjusting for age, site, visit, race/ethnicity, education, family history of HTN, smoking status, medication use (i.e., anticoagulant, heart disease medication, insulin, hormone [estrogen, progesterone, and birth control pills]), BP medication use, and menopausal and diabetes status (Table 3).

Waist circumference as a mediator

As shown in Table 3, the observed associations between everyday discrimination exposure and BP in both the semiadjusted and fully adjusted models were attenuated with further adjustment for waist circumference (SBP fully adjusted model: 0.25; 95% CI: −0.63, 1.14; DBP fully adjusted model: 0.36; 95% CI: −0.20, 0.91). Over the follow-up, waist circumference was significantly related to SBP (data not shown in table; 0.26; 95% CI: 0.23, 0.28) and DBP (data not shown in table; 0.14; 95% CI: 0.13, 0.16) and was also a significant mediator of the association between everyday discrimination exposure and SBP (indirect effect: 1.05; 95% CI: 0.75, 1.35) and DBP (indirect effect: 0.58; 95% CI: 0.40, 0.75). That is, exposure to everyday discrimination predicted increased waist circumference over follow-up, which in turn was associated with increased SBP and DBP.

Table 2 Everyday discrimination exposure[a] at baseline predicting BMI[a] and waist circumference[b] over the 10 year follow-up period in SWAN participants in the full sample and stratified by race/ethnicity[c]

	Waist circumference (*N* = 2,177)				BMI (*N* = 2,180)			
	Estimate	*SE*	95% CI	*p* Value	Estimate	*SE*	95% CI	*p* Value
Full sample	4.06	0.58	(2.94, 5.19)	<.0001	1.62	0.26	(1.12, 2.12)	<.0001
Stratified by race/ethnicity								
Black	3.57	1.34	(0.94, 6.19)	.008	1.57	0.65	(0.29, 2.84)	.02
White	5.13	0.84	(3.47, 6.79)	<.0001	2.02	0.36	(1.31, 2.73)	<.0001
Chinese	1.21	1.20	(−1.14, 3.55)	.31	0.80	0.47	(−0.12, 1.72)	.09
Hispanic[c]	0.06	2.48	(−4.80, 4.92)	.98	-0.75	1.16	(−3.02, 1.51)	.52
Japanese	3.62	1.17	(1.33, 5.91)	.002	1.23	0.46	(0.32, 2.14)	.01

[a]Everyday discrimination exposure (yes) was determined when respondents indicated that any type of everyday discrimination occurred at least "sometimes" or "often." BMI, M (*SD*). kg/m^2.

[b]Waist circumference in cm.

[c]Hispanic women were missing follow-up data from visits 7 and 8.

Table 3 Everyday discrimination exposure[a] at baseline predicts increases (95% CI) in SBP and DBP over the 10 year follow-up period in SWAN participants

	Model 1[b]	Model 2[c]	Model 3[d]	Model 4[e]
Everyday discrimination exposure in models including covariates and waist circumference (N = 2,177)				
SBP	2.19 (1.21, 3.16)**	1.25 (0.31, 2.19)*	0.74 (−0.16, 1.63)	0.25 (−0.63, 1.14)
DBP	0.99 (0.41, 1.56)**	0.89 (0.32, 1.46)*	0.36 (−0.21, 0.92)	0.36 (−0.20, 0.91)
Everyday discrimination exposure in models including covariates and BMI (N = 2,180)				
SBP	2.19 (1.21, 3.16)**	1.25 (0.31, 2.19)*	0.65 (−0.25, 1.55)	0.22 (−0.68, 1.11)
DBP	0.99 (0.41, 1.56)**	0.90 (0.32, 1.46)*	0.36 (−0.21, 0.93)	0.39 (−0.18, 0.95)

SBP systolic blood pressure; *DBP* diastolic blood pressure.

[a]Everyday discrimination exposure (yes) was determined when respondents indicated that any type of everyday discrimination occurred at least "sometimes" or "often."

[b]Adjusted for age and time.

[c]Adjusted for Model 1, site, race/ethnicity, education, family history of hypertension, smoking status, medication use (anticoagulant, heart medication, and insulin), hormone (estrogen, progesterone, and birth control pills), blood pressure medication use, and menopausal and diabetes status.

[d]Adjusted for age, time, and adiposity (BMI or waist circumference).

[e]Adjusted for Model 2 and adiposity (BMI or waist circumference).

*$p \leq .01$; **$p \leq .001$.

BMI as a mediator

Similar to the results for waist circumference, the associations between everyday discrimination exposure and BP were attenuated with adjustment for BMI (SBP model: 0.22; 95% CI: −0.68, 1.11; DBP model: 0.39; 95% CI: −0.18, 0.95; Table 3). Over the follow-up, BMI was significantly related to SBP (data not shown; 0.65; 95% CI: 0.59, 0.72) and DBP (data not shown; 0.33; 95% CI: 0.28, 0.37) and was also a significant mediator of the association between everyday discrimination exposure and SBP (indirect effect: 1.06; 95% CI: 0.70, 1.39) and DBP (indirect effect: 0.53; 95% CI: 0.35, 0.70). As with waist circumference, exposure to everyday discrimination predicted increased BMI over follow-up, which in turn was associated with increased SBP and DBP.

Race/ethnicity, waist circumference, and BMI as moderators

The association of everyday discrimination exposure to SBP and DBP did not vary by race/ethnicity (p = .54 and p = .75, respectively). There were also no associations observed for everyday discrimination exposure or everyday discrimination exposure x race/ethnicity and HTN (p = .85 and p = .87, respectively). Finally, associations of everyday discrimination exposure to SBP, DBP, or HTN were not moderated by waist circumference (SBP: p = .21; DBP: p = .44; HTN: p = .78) or BMI (SBP: p = .25; DBP: p = .17; HTN: p = .21).

Sensitivity Analyses

In analyses examining waist circumference as a mediator but excluding women who, at baseline, reported exposure to everyday discrimination and selected their appearance as the main reason for these experiences (n = 116 excluded), results were similar to those reported above. Exposure to everyday discrimination at baseline was a significant predictor of waist circumference over follow-up (3.23, 95% CI: 2.11, 4.36). Exposure to everyday discrimination predicted SBP (1.08, 95% CI: 0.11, 2.04) and DBP (0.89, 95% CI: 0.30, 1.48) in models fully adjusted for covariates; however, these associations were attenuated after adjusting for waist circumference (SBP: 0.28, 95% CI: −0.63, 1.19; DBP: 0.45, 95% CI: −0.12, 1.03). Results were similar in models testing BMI as a mediator (n = 112 excluded). Everyday discrimination exposure at baseline predicted BMI over follow-up (1.19, 95% CI: 0.70, 1.69). Exposure to everyday discrimination predicted SBP (1.08, 95% CI: 0.11, 2.04) and DBP (.89, 95% CI: .30, 1.48) in models fully adjusted for covariates; however, these associations were attenuated after adjusting for BMI (SBP: 0.28, 95% CI: −0.63, 1.19; DBP: 0.5, 95% CI: −0.12, 1.03).

Discussion

This is the first study to demonstrate longitudinal linkages among everyday discrimination, adiposity, and BP, three factors that are independently linked to established health disparities in the USA. Specifically, in a racially/ethnically diverse cohort of women, we observed that as follows: (a) exposure to everyday discrimination at baseline predicted increased BP across a 10 year follow-up; (b) this association did not change when relevant demographic, behavioral, or medical factors were accounted for; and (c) greater adiposity over time (as measured by waist circumference or BMI) partially explained

this positive association. Specifically, women reporting exposure to everyday discrimination at baseline had increased adiposity over the follow-up period as indicated by waist circumference and BMI and, in turn, had higher SBP and DBP over time. Notably, these associations did not vary by race/ethnicity and did not predict HTN risk. Overall, these findings demonstrate the utility of considering the complex interplay among psychosocial, behavioral, and clinical health endpoints in our pursuit to understand health disparities.

The potential implications of these findings may have import from a public health perspective. Changes in BP are incremental over time and each increase, even without reaching clinical HTN status, creates greater risk for CVD sequelae [72]. A meta-analysis of individual data for 1 million, normotensive adults across more than 60 prospective studies confirmed a continuous, positive relationship to CVD risk throughout the normal range of usual BP (down at least as far as 115/75 mmHg; 50). These data also demonstrated that even a 2 mmHg lower usual SBP would contribute to $\approx$10 per cent lower stroke mortality and $\approx$ 7 per cent lower mortality from ischemic heart disease or other vascular endpoints in middle age. Thus, the public health import is of note as the application of a lens explicit to the individual-level, clinical implications of the current findings may obscure the meaningfulness of these findings given their smaller magnitude.

This linkage of discrimination to increased BP via adiposity is certainly plausible within the context of a biopsychosocial framework. Prior studies have posited that interpersonal discrimination acts as a chronic stressor resulting in neuroendocrine dysregulation (e.g., Ref. 73). The neurobiological mechanisms through which the body's response to stress and stress-responsive eating affect weight include dysregulation of glucose metabolism, insulin sensitivity, and other hormones including ghrelin, related to energy homeostasis [36]. Additionally, unhealthy behaviors (e.g., food choices and physical activity) are more prevalent in the context of stress [22]. Thus, increases in weight are thought to lead to increases in BP in part through dysregulation of sympathetic activation [74]. Consideration of the biological pathways linking discrimination to BP helps us to further elucidate how this chronic stressor might be acting upon health disparities.

These findings extend prior studies which have reported null prospective [27] and largely mixed cross-sectional [75] associations between interpersonal discrimination and resting BP or HTN primarily conducted in Blacks. Perhaps prior studies examining the main effect of discrimination on BP have yielded largely null results because biological factors were not considered as pathways, but as adjustment variables. Researchers have postulated that dysregulation of the hypothalamic–pituitary–adrenal axis, as well as behavioral responses, may be central to the ways in which discrimination "gets under the skin" [76]. Thus, intermediary pathways that we traditionally treat as confounders or adjustment variables may elucidate the linkages of psychosocial processes to these cardiovascular endpoints. Everyday discrimination is linked to BP, but once adiposity is considered vis à vis waist circumference or BMI, this prospective finding is fully attenuated.

Interestingly, there were no variations in the linkage of everyday discrimination to BP by race/ethnicity. This suggests that the relation of this particular form of interpersonal discrimination to BP is not more pronounced among certain racial/ethnic minorities compared with others including racial/ethnic nonminority groups. Prior studies have reported similar findings using this particular measure [77, 78]. Although this is plausible, we caution in making the argument that race/ethnicity not be considered as an important source of stress and of greater exposure to bias in the form of racism specifically and in experiences of interpersonal discrimination overall. Indeed, racial/ethnic minorities carry a significantly higher burden of chronic health diseases, which has not been fully accounted for by traditional risk factors [9]. Future work should consider the various channels through which race/ethnicity–related bias may operate. For instance, considering the implications of intergenerational transmission and structural discrimination (e.g., residential segregation) as well as more general indices of interpersonal discrimination such as everyday discrimination alongside race/ethnicity–specific one-on-one experiences (e.g., racial discrimination) may be warranted. Such studies may also benefit from assessments of vicarious exposures to race/ethnicity–related bias as well [79].

Surprisingly, everyday discrimination did not predict HTN risk. This finding is consistent with most prior findings, which are cross-sectional [12, 75]. It is plausible that masked HTN was a factor. Some individuals with normal office BP have elevated ambulatory BP when this modality is used, and thus have masked HTN [80]. It is estimated that approximately 12.3% of the adult population has masked HTN [80]. Consideration of multiple modalities to concurrently assess HTN status (e.g., clinic and ambulatory BP monitoring) may be warranted in future prospective studies.

Limitations

Although this study enables us to better understand the prospective relation of everyday discrimination to BP and subsequent CVD risk, challenges must be noted to inform future research. Perhaps simultaneous assessment

of various dimensions of interpersonal discrimination (e.g., major lifetime and everyday racial/ethnic discrimination) would yield a more comprehensive understanding of the linkages of bias to BP. Regarding BP measurement, although staff were certified, trained technicians and utilized a traditional clinic BP protocol—the gold standard in BP assessment—[81], two factors should be considered. First, self-report of antihypertensive use may have contributed to misclassification bias. Even though this approach is widely used in epidemiological research [67], this may have impeded HTN classification. Second, ambulatory BP may be a more powerful way to capture BP. Several studies (see review [66, 82]) have documented a significant association between interpersonal discrimination and HTN risk using ambulatory BP, measured at multiple intervals throughout the day, as an outcome. Although resting BP has been the traditional means of assessment in clinical settings, some have argued that ambulatory BP is a stronger predictor of long-term risk for HTN and its sequelae [83]. Although clinic BP is not able to capture BP across settings that individuals are likely to negotiate in their daily lives [84], ambulatory BP is capable of just that. Furthermore, in line with "masked hypertension" and "white coat hypertension" phenomena, it is plausible that clinic BPs could be misclassified, thus obscuring the relation of everyday discrimination to elevated BP [85].

Although SWAN offered the unique opportunity to investigate longitudinal associations among multiracial/ethnic women across the menopausal transition, several important methodological limitations arose as a consequence of analyzing a preexisting dataset. For one, we cannot fully rule out the possibility that increased waist circumference or BMI at baseline caused increased discrimination. Although results of a sensitivity analysis in this sample showed that the associations among everyday discrimination, adiposity, and BP were similar after excluding those who attributed their experiences with discrimination primarily to their appearance, the prevalence and consequences of weight discrimination are well-documented (i.e., Ref. 86). Additionally, there was regional variation in recruitment strategies, all sampling was not completely random, and women of each race/ethnicity were recruited from different geographic regions. Thus, geographic differences may have contributed to variations in obesity rates, exposure to interpersonal discrimination, and other relevant factors. However, it is important to note that we adjusted for study site, and the observed associations did not vary by racial/ethnic group. Finally, we did not investigate all potential moderators of the association between everyday discrimination and BP (e.g., stress of menopausal transition), and the possibility that these relationships could be exacerbated or buffered by third factors is an interesting avenue for future research (e.g., see Ref. 17).

Conclusion

To the best of our knowledge, this is the first study to examine the relation of everyday discrimination to BP and HTN risk prospectively and in a racially/ethnically diverse sample including both minority and nonminority racial/ethnic groups. The current findings demonstrate that exposure to interpersonal discrimination in the form of everyday discrimination is related to increases in BP over time; however, discrimination did not predict incident HTN. Future studies investigating various forms of interpersonal (e.g., racial, nonracial, major, lifetime, and everyday) bias and structural sources of discrimination in relation to HTN risk that incorporate both resting and ambulatory BP measurements utilizing a quasiecological momentary, longitudinal design may hold the most promise for further disentangling the linkages among these factors. Thus, elucidating the multilevel patterning and influence of discrimination on established health disparities is a critical next step.

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Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards Authors Danielle L. Beatty Moody, Yue Fang Chang, Elizabeth J. Pantesco, Taylor M. Darden, Tene T. Lewis, Charlotte Brown, Joyce T. Bromberger, and Karen A. Matthews declare that they have no conflicts of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Authors' Contributions Danielle L. Beatty Moody conceived of the idea for this manuscript. Karen A. Matthews supported access to the SWAN dataset. Yue-Fang Chang carried out the statistical analyses. Danielle L. Beatty Moody and Elizabeth J. Pantesco interpreted the analyses with assistance from Yue-Fang Chang and Karen A. Mathews. Danielle L. Beatty Moody, Elizabeth J. Pantesco, and Taylor M. Darden wrote the manuscript, with additional critical feedback provided by Tené T. Lewis, Charlotte Brown, Joyce T. Bromberger, and Karen A. Matthews. All authors reviewed and discussed the results and contributed to the final manuscript.

Ethical Approval All procedures performed in this study of human participants were in accordance with the ethical standards of the affiliated institutional and research committees.

Informed Consent After a complete description of the study, informed consent was obtained from all SWAN study participants.

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