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White matter hyperintensities in diverse populations: A systematic review of literature in the United States

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ABSTRACT

As the United States' (US) elderly population becomes increasingly diverse, it is imperative that research studies address cognitive health in diverse populations of older Americans. White Matter Hyperintensities (WMH) are useful imaging findings that can be studied in elderly individuals and have been linked to an increased risk of neurological conditions, such as stroke, cognitive impairment, and dementia. We performed a systematic review of literature using PubMed sources to compile all the studies that investigated the prevalence of ethnic and racial differences of WMH burden amongst diverse groups in the US. We identified 23 unique articles that utilized 16 distinct cohorts of which 94 % were prospective, longitudinal studies that included community-based and family-based populations. The overall results were heterogenous in all aspects of data collection and analysis, limiting our ability to run meta-analyses and draw definitive conclusions. General observations suggest increased vascular risk on African American populations, contributing to greater WMH burden in that population. Overall, the findings of this study indicate a need for a standardized approach to investigating WMH in efforts to measure its clinical impact on diverse populations.

Introduction

The United States' (US) population is not only aging rapidly, but also becoming rapidly more racially and ethnically diverse. by 2060, it is estimated that people of non-White racial and ethnic backgrounds will comprise nearly half of the US population aged 65 years and older [1]. Yet, most of our understanding about the aging brain comes from studies that consist of participants predominantly of non-Hispanic White background.

Lack of ethno-racial diversity in aging and dementia studies is problematic. Aging and cognitive health are directly impacted by psychosocial and environmental determinants that particularly affect older, more diverse populations in the US. These disparities manifest into inequitable outcomes that can be grouped into racial and ethnic categories. For instance, African Americans have the highest incidence of vascular risk factors and disproportionate rates of stroke and cerebrovascular disease in the US [2]. Diabetes is also twice as prevalent in African Americans and Hispanic populations compared to non-Hispanic White Americans [2]. Additionally, African Americans and Hispanic populations have higher likelihoods to develop dementia compared to their White counterparts [3]. Yet, despite a higher prevalence of risk factors, ideal control is less common [2] and associated with increased risk for cognitive impairment [4]. These health inequities are partially the consequences of historical and structural racism that impact cognitive health through mechanisms of poverty and lack of available or affordable healthcare [5]. It is therefore critical to incorporate diversity of race and ethnicity in neuroimaging studies of older adults, not only to better represent the US population, but also to examine the underlying causes and consequences of these disparities.

White matter hyperintensities (WMH) are a common finding on neuroimaging studies of older adults. While they may result from multiple pathologies including Alzheimer's Disease (AD) [6], among cognitively normal individuals, WMH are considered a hallmark imaging feature of cerebral small vessel disease (SVD) of the brain [7,8]. It is hypothesized that dysfunction of the brain's microvasculature results in hyperintense signals of T2-weighted and Fluid Attenuated Inversion Recovery (FLAIR) magnetic resonance imaging (MRI) of the white matter [9]. While WMH are commonly seen among cognitively normal individuals, there is also substantial evidence that larger WMH burdens are associated with an increased risk of neurological conditions, such as stroke, cognitive impairment, and dementia [10].

Several studies have examined the relationship between WMH and

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race/ethnicity, though, to our understanding, no thorough review on this matter has been previously published. The aim of this study, therefore, is to systematically review published works on PubMed that investigated WMH in diverse populations of people in the US to better understand the available literature and discuss future directions.

Methods

Search strategy

We conducted a systematic review of literature in English, using PubMed sources and the PRISMA statement as guidance [11].

Inclusion and exclusion criteria

PubMed papers were identified based on a search query that contained three major categories: WMH, diversity, and cognition. To refer to WMH, the following terms were searched in all fields: white matter hyperintensities, white matter hyperintensity, WMH, white matter signal. To refer to diversity, we used the minority health search strategy portion of the MEDLINE®/PubMed® Health Disparities and Minority Health Search Strategy [12]. To refer to cognition, the following terms were searched in all fields: cognition, cognitive decline, cognitive impairment, cognitive performance, cognitive disorder, mild cognitive impairment, MCI, aging, dementia, vascular dementia, VCID, vascular disease, hypertension, risk factors, stroke, cerebrovascular disease, infarction, Alzheimer's Disease, AD, mortality, death.

Studies conducted outside the US were also excluded to focus on the growing diversity and inequities affecting US populations.

Identified publications

A total of 307 articles were identified based on our search query conducted in September of 2022. 6 additional articles were manually included after our initial search based on relevant citations and recommendations from leading researchers in this domain of research. The 313 articles were screened based on title and abstract. Of these 313 articles, 258 sources were excluded due to lack of relevancy, resulting in 55 articles that were further reviewed as full text. To qualify for full text review, sources must have examined the interaction of race/ethnicity across two or more ethno-racial groups. These articles were further divided into primary or secondary sources. A source was considered primary if the focus of the manuscript was to describe ethno-racial differences in WMH burden. A source was considered secondary if two or more ethno-racial differences in WMH burden were reported but the primary emphasis of the manuscript focused on other associations such as association between WMH burden and cognition. After thorough review, a total of 23 articles met inclusion criteria (Fig. 1).

Ethno-racial terminology

For the purposes of this study, African Americans is the term used to encompass studies that used terminology of "African Americans," "Black Americans," and "Black". White Americans is the term used to encompass studies that used terminology of "Whites," "European Americans," "non-African Americans," "non-Hispanic Whites," and "Caucasian." Hispanics is the term used to encompass terminology of "Hispanics," "Mexican Americans," "Latinos/Latinx."

Risk of bias assessment

We used the Risk of Bias Assessment Tool for Nonrandomized Studies (RoBANS) to assess study bias. RoBANS is a validated and reliable instrument used in systematic reviews to analyze and evaluate the risk of bias of the sources reviewed [13]. Using this tool, 6 categories of risk bias were assessed independently by authors VF and CD and characterized as "high," "low," or "unclear."

Methodologic limitation

Due to the heterogeneity of the study designs, meta-analyses could not be performed as this calls for a standardized approach. Consequentially, we performed a structured review focused on similarities and differences amongst the various studies.

Results

Cohorts

Our systematic review search strategy generated 23 full text articles identified through PubMed searches. These 23 articles comprised of 16 unique study cohorts. These cohorts include the Healthy Aging Brain in Latino Elders (HABLE) study [14], Multi-Ethnic Study of Atherosclerosis (MESA) [15], Atherosclerosis Risk in Communities (ARIC) study [16–21], Washington Heights-Inwood Columbia Aging Project (WHICAP) [22–24], Offspring Study of Racial and Ethnic Disparities in Alzheimer Disease (WHICAP Offspring) [24], Diabetes Heart Study (DHS)-Mind [25], Genetic Study of Atherosclerosis Risk (GeneSTAR) [26], Harvard Aging Brain Study [27], University of California Davis (UC Davis) Aging Diversity Cohort [28,29], Emory Alzheimer's Disease Research Center(ADRC) sample [30], Northern Manhattan Study (NOMAS) [31], Knight ADRC sample [32], Dallas Heart Study [33], Action to Control Cardiovascular Risk in Diabetes Memory in Diabetes (ACCORDION MIND) trial [34], Cardiovascular Health Study (CHS) [35], and Alzheimer's Disease Neuroimaging Initiative (ADNI) [36].

Demographics

These 23 studies comprised a total of 24,426 total participants[1] with an average age of 68.8 years. Among those 24,426 participants, 55 % were classified as White ($n = 13{,}429$), 30 % were classified as African American ($n = 7322$), and 13.9 % were classified Hispanics ($n = 3393$). Only 0.6 % were classified as Asian Americans ($n = 155$) and 0.5 % were classified as Other ($n = 127$) (Fig. 2).

Study design

The strength of the evidence was limited to 94 % community and family-based, prospective observational cohort studies with differing inclusion and exclusion criteria, none of which utilized common statistical practices to equate findings to the general population [37] (Table 1a). Representativeness, particularly among non-White subjects, is, therefore, likely to be limited. Though there is substantial overlap amongst cohorts studied in the 23 articles, the scientific objectives of each study differed significantly. 70 % of the studies investigated qualitative associations between some combination of WMH, cardiovascular risk factor, measure of cognition, and ethno-racial groupings. In comparison, 30 % of the studies were designed to quantify and compare WMH between one ethnicity to another. Moreover, 70 % of articles considered cross sectional analysis, while the remaining 30 % looked at longitudinal differences or both. Numerical proportions of study design characteristics are summarized in Table 1b.

Health history

In addition to collecting data on WMH, 22 out of 23 articles also explicitly reported health histories on subjects participating in their

[1] 24,426 represents the total participants not considering study overlap. However, our calculations are limited in that many of the articles shared cohorts, and therefor the true total is less than 24,426.

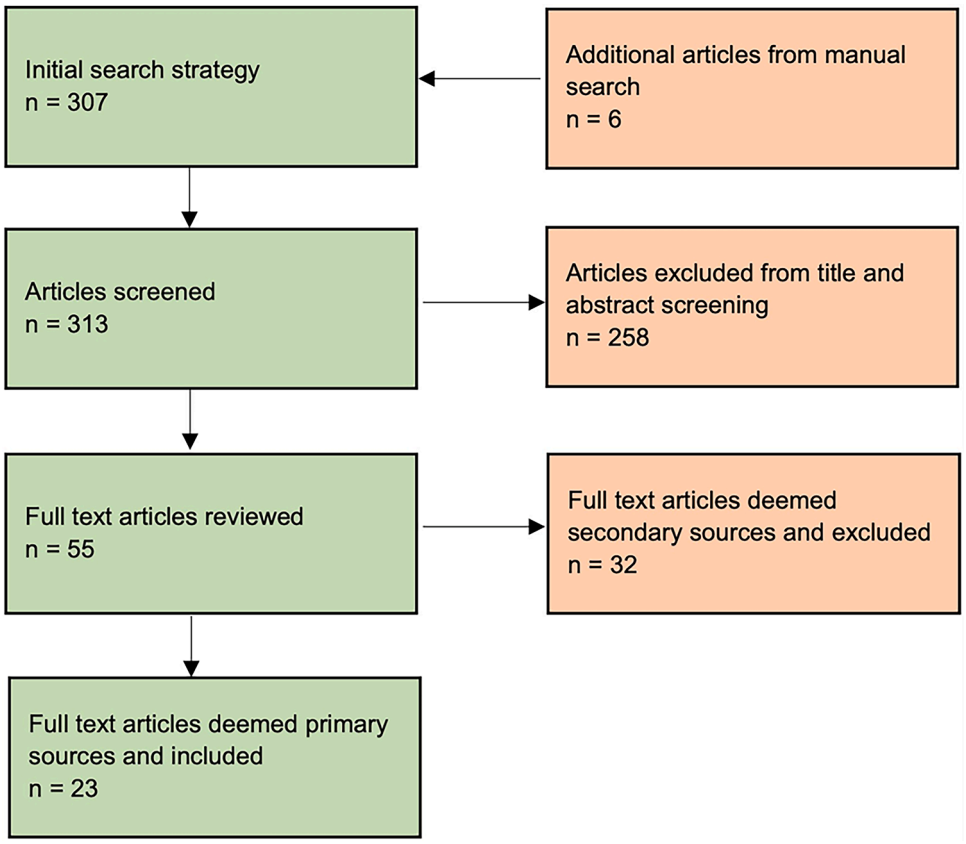

Fig. 1. Prisma flow diagram describing details of the selection process.

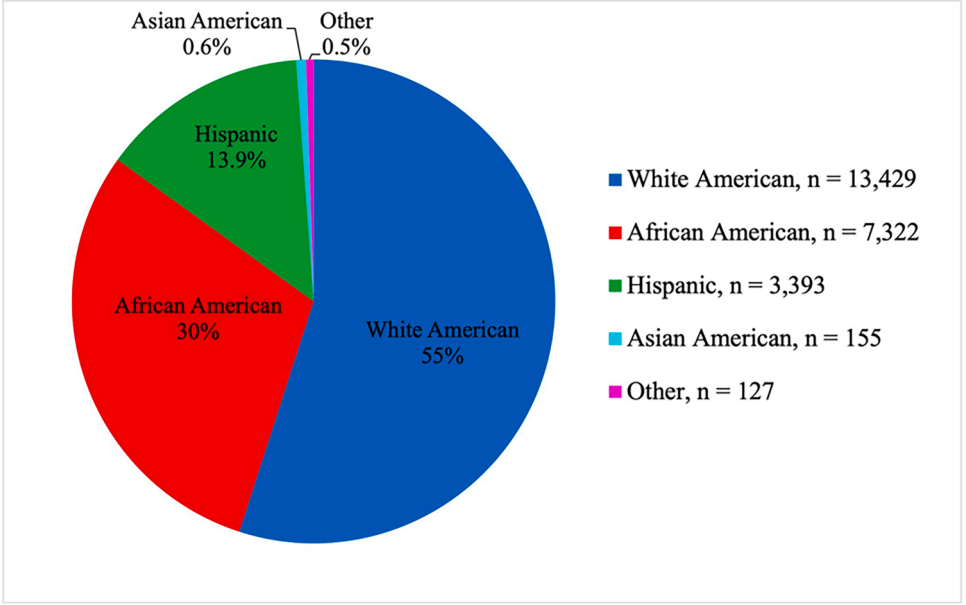

Fig. 2. Pie chart illustrating numerical proportions of White American, African American, Hispanic, Asian American, and Other ethno-racial groups.

studies. Researchers from ACCORDIAN MIND trial did not provide detailed reports of their co-variates and will thus be excluded in this analysis of health histories [34]. While there are many health and environmental factors that can influence WMH prevalence and extent, there was no consensus amongst researchers of the types of medical history collected. Consequently, the reported co-occurring health information varied considerably. Only age, sex, and ethnicity/race were consistently reported in all 22 articles that reported detailed health histories. Other common covariates, however, included glucose/diabetes status (17 out of 22), blood pressure/hypertension status (17 out 22), cholesterol/hyperlipidemia status (7 out of 22), and smoking status (9 out of 22). The main socioeconomic factor that individual reports considered was level of education level (16 out of 22), with only one study considering income level in addition. A complete detailing of

Table 1a
Cohort and study design with demographics.

Study Name [citation]	HABLE [14]	MESA [15]	ARIC [16–21]	WHICAP [22–24]	Offspring [24]	DHS-Mind [25]	GeneSTAR [26]	Harvard Aging Brain Study [27]	UC Davis Aging Diversity Cohort [28,29]	Emory ADRC sample [30]	NOMAS [31]	Knights ADRC sample [32]	Dallas Heart Study [33]	ACCORDIAN MIND trial [34]	CHS [35]	ADNI [36]
Study design	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	family-based prospective observational cohort study	family-based prospective observational cohort study	family-based prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	community-based, prospective observational cohort study	Observational extension of randomized study	community-based, prospective observational cohort study	community-based, prospective observational cohort study
Demographic	Hispanics Whites	African Americans Asian Americans Hispanics Whites	African Americans Whites	African Americans Hispanics Whites	African Americans Hispanics Whites	African Americans Whites	African Americans Whites	African Americans Whites	African Americans Hispanics Whites	African Americans Whites	African Americans Hispanics Whites	African Americans Whites	African Americans Hispanics Whites	African Americans Hispanics Whites	African American White	African American White
WMH Measurement Method	Volumetric	Volumetric	Semi-quantitative	Volumetric	Volumetric	Semi-quantitative	Semi-quantitative Volumetric	Volumetric	Volumetric	Volumetric	Volumetric	Volumetric	Volumetric	Volumetric	Semi-quantitative	Volumetric

reported health and social-cultural factors is included in the supplementary materials to this manuscript (Supplemental Table 1).

Cognitive status

Given that nearly all studies were community based, only 4 reported details of clinical evaluation to determine the presence or absence of cognitive impairment [22,28,29,36]. 3 of these studies included individuals with mild cognitive impairment (MCI) and dementia [22,28,29,36]. See supplemental table 2 for breakdown of cognitive status.

Methods used to measure WMH burden

Methods of WMH burden varied over time from semi-quantitative to quantitative methods, with many early publications using a semi-quantitative approach based on a common categorical ranking of WMH [38]. Quantitative methods included FLAIR based image analysis such as those described in the WHICAP [39], NOMAS [40], and the UC Davis Diversity Cohort [28]. Table 1a summarizes the methods used for each study.[1]

Quality assessment

15 out of 23 articles scored low in bias assessment in all six RoBANS categories [13]. The four studies that rated high bias for selection of participants included less than 25 % diverse participants [25,27,32,36]. The three studies that rated high bias for confounding variables did not adjust beyond age, sex, and ethnicity [20,21,35]. The one study that rated high bias for incomplete outcome data failed to provide health history [34]. See Table 2 for complete RoBANS analysis.

Study date

Our search identified multiple studies done early in the era of WMH research as well currently. Given the differing conclusions drawn from these studies, we describe them separately.

Early studies

The earliest study that reported on the prevalence of racial differences of white matter lesions was published in 1996 using a semi-quantitative rating scale of WMH severity [20]. Researchers examined the association between white matter lesions and hypertension in a community sample of 1920 African Americans and White elderly participants in ARIC. They found that hypertension is associated with increased odds of white matter lesions and that this association was stronger in African Americans than in White Americans after adjusting for age, sex, smoking, diabetes, and total cholesterol. In subsequent publication by the same group of researchers from the same cohort, they conclude that African Americans exhibit a higher proportion of both normal and severe white matter lesions than White Americans after adjusting for age, sex, and ethnicity [21]. Then in 1997, researchers reporting data from the CHS cohort which also focused solely on African Americans and Whites, concluded that white matter grade was significantly greater among African Americans [35]. Results of these studies are summarized in Table 3.

More recent studies

While early studies concluded prevalent ethno-racial differences in WMH [20,21,35], these initial studies were limited to comparisons between African Americans and Whites along with utilization of limited covariates to account for potential population differences that could influence WMH burden. More recent studies have considered the impact of vascular health and life-style factors that could contribute to WMH burden differences amongst diverse populations. Though there is no

Table 1b
Numerical breakdown of study designs and characteristics.

Category	Subcategory	Results (n)	Result%
Demographics of interest	White American	23	100
	African American	22	96
	Hispanic	10	43
	Asian American	1	4
Cohorts	Community-based	12	75
	Family-based	3	19
	Observational extension of randomized-study	1	6
Study Primary Outcome	Association study	16	70
	Comparative differences of WMH	7	30
Study Analysis	Cross sectional analysis	16	70
	Longitudinal analysis	5	22
	Both	2	9

Table 2
Quality Assessment with ROBAS Instrument. Red = high risk of bias, Green = low risk of bias, Yellow = unclear according to the review authors.

Study	Selection of participants	Confounding variables	Measurement of exposure	Blinding of outcome assessments	Incomplete outcome data	Selective outcome reporting
King KS et al. [14]	Low	Low	Low	Low	Low	Low
Austin TR et al. [15]	Low	Low	Low	Low	Low	Low
Gottesman RF et al. [16]	Low	Low	Low	Low	Low	Low
Gottesman RF et al. [17]	Low	Low	Low	Low	Low	Low
Power MC *et al.* [18]	Low	Low	Low	Low	Low	Low
Knopman DS et al. [19]	Low	Low	Low	Low	Low	Low
Liao D et al. [20]	Low	High	Low	Low	Low	Low
Liao D et al. [21]	Low	High	Low	Low	Low	Low
Brickman AM et al. [22]	Low	Low	Low	Low	Low	Low
Zahodne LB et al. [23]	Low	Low	Low	Low	Low	Low
Turney IC et al. [24]	Low	Low	Low	Low	Low	Low
Divers J et al. [25]	High	Low	Low	Low	Low	Low
Nyquist PA et al. [26]	Low	Low	Low	Low	Low	Low
Amariglio RE et al. [27]	High	Low	Low	Low	Low	Low
DeCarli C et al. [28]	Low	Low	Low	Low	Low	Low
Gavett BE et al. BE [29]	Low	Low	Low	Low	Low	Low
Howell JC et al. [30]	Low	Low	Low	Low	Low	Low
Rundek T et al. [31]	Low	Low	Low	Low	Low	Low
Meeker KL et al. [32]	High	Low	Low	Low	Low	Low
King KS et al. [33]	Low	Low	Low	Low	Low	Low
Herman AL et al. [34]	Low	Low	Low	Low	High	Low
Yue NC et al. [35]	Low	High	Low	Low	Low	Low
Morrison C et al. [36]	High	Low	Low	Low	Low	Low

consensus as to what these cardiovascular risk and life-style factors may be, the literature suggests mainly age and the presence of hypertension are most proximate factors that drive WMH burden [41]. When accounting for these factors, ethno-racial differences appear to diminish. For example, one study showed that differences in WMH between White and African Americans in a minimally adjusted model attenuated after the adjustment for vascular and socioeconomic factors [15]. Other studies showed a stronger association between cardiovascular risk factors and WMH in African Americans [17,22,31,33] and Hispanics [14, 29,31] compared to White Americans, which are believed to be driving the observed WMH differences. A WHICAP study conducted in 2008 examined racial differences in the distribution of WMH in White, Hispanic and African Americans adjusting for group differences in age, sex, education and self-reported history of vascular risk factors and disease [22]. The researchers concluded that African Americans had a greater WMH volume associated with vascular risk and disease that partially explained differences between Whites, Hispanics, and African Americans. These results suggest that disparities in health factors (and possibly the treatment) likely contribute to previously reported excess burden of WMH in African Americans and to a lesser extent Hispanics. Results of the studies mentioned are summarized in Table 4.

Discussion

The results of this systematic review were inconclusive and cannot definitively address the presence of ethno-racial differences among WMH in diverse populations. Instead, this review highlights a current knowledge gap regarding differences in WMH burden amongst various ethno-racial groups. Differences in study design, inclusion and exclusion criteria, use of differing covariates to adjust for group differences as well as lack of applied population inferential statistical methods, limits any definitive conclusions on the interaction between race/ethnicity and

Table 3
Summary of Early Studies of Racial Differences in WMH.

Citation	PMID	Title	Journal	First Author (Publication Date)	Cohort	Study Design	Study Outcome	Study Stratifications	Concluded Ethno-racial Differences?
20	8969791	Presence and severity of cerebral white matter lesions and hypertension, its treatment, and its control. The ARIC Study. Atherosclerosis Risk in Communities Study. Stroke.	Stroke	Liao D (1996)	ARIC	Cross sectional	Association of WML with blood pressure, hypertension, and its treatment and control.	Age Sex Smoking Diabetes Total cholesterol	Yes
21	9159770	The prevalence and severity of white matter lesions, their relationship with age, ethnicity, gender, and cardiovascular disease risk factors: the ARIC Study. Neuroepidemiology.	Neuroepidemiology	Liao D (1997)	ARIC	Cross sectional	Prevalence, severity and correlates of WMLs	Age Sex Ethnicity	Yes
35	8988189	Sulcal, ventricular, and white matter changes at MR imaging in the aging brain: data from the cardiovascular health study	Radiology	Yue NC (1997)	Cardiovascular Health Study	Cross sectional	Distribution of changes in sulcal size, ventricular size, and white matter signal intensity	Age Race Sex	Yes

WMH based on current data, although some general observations are worth mentioning. First, the number of studies meeting criteria for review suggest that this topic is of scientific importance. Second, the ability to gather imaging data from large diverse communities is feasible and will likely expand in response to NIH initiatives (eg. NOT-OD-20–031). Third, nearly all the studies reviewed suggest that WMH are averse to brain health. The overwhelming limitation of this review, however, is the lack of consistencies in study design, including subject recruitment and covariates.

Consequently, there are differing, and sometimes contradictory, conclusions made in every article of this study. The most consistent conclusion found in this systematic review, however, were that 10 out of 23 studies concluded some degree of greater vascular risk factors associated with greater WMH burden in African Americans compared to other groups. We interpret these claims in the context that race and ethnicity are social cultural constructs that have no genetic basis [42]. In fact, the Human Genome Project found that humans are 99.9 % genetically identical and the 0.1 % difference cannot be categorized into ethno-racial categories [43]. Any observed differences, therefore, likely result from by non-biological factors, such as life-style, health, and socioeconomic conditions, including access to health care [44]. Limited available data reviewed here indicate that accounting for these confounding factors reduces and might eliminate the reported ethno-racial differences.

Other limitations to these data also exist. For example, of the 16 unique cohorts, only MESA [15] included participants not identifying as White, African American, or Hispanic and few considered even these three groups simultaneously [22–24,28,29,31,33], making conclusions regarding differences amongst all older Americans even more difficult. Further, given that AD is also associated with increased WMH burden [45–47] and only one study reviewed examined concomitant AD biomarkers [27], a more complete characterization of cognitive status as well as concurrent AD pathology, therefore, will also be necessary to fully understand any ethno-racial differences. For example, Asian Americans and Native Americans have lower incidence of dementia and AD compared to other groups [48], and therefore, the inclusion of other populations could have provided greater insights on the study of ethno-racial differences in WMH and the potential impact of cognitive decline and incident dementia. Additionally, more longitudinal analysis is needed to evaluate the progressive clinical impact of WMH in different ethno-racial groups. There is also limited research investigating regional differences as opposed to global differences in the distribution of WMH amongst diverse populations, with only one study in our systematic review investigating for region-specific differences [36]. Finally, our systematic review runs the risk of publication bias, where studies that find no ethno-racial differences may fail to be reported.

Conclusion

Understanding the factors that impact WMH amongst diverse populations will likely have substantial public health impact [49], particularly given that substantial WMH burden leads to stroke, dementia and death [10] and non-White populations appear to have different pathological causes for dementia [50–52]. Since vascular factors are treatable and potentially preventable, a complete understanding of the impact of vascular disease on brain health among non-White persons in the US could lead to better brain health thereby reducing the health care burden of this enlarging segment of our population. We hope that this systematic review will help to guide future research on vascular factors, WMH, and cognition among diverse populations that might lead to insights related to clearer identification of at-risk individuals for whom brain health can be better maintained.

CRediT authorship contribution statement

Vista Farkhondeh: Conceptualization, Data curation, Formal

Table 4
Summary of More Recent Studies of Racial Differences in WMH.

Citation	PMID	Title	Journal	First Author (Publication Date)	Cohort	Study design	Study Outcome	Study Stratifications	Concluded Ethno-racial Differences?
14	35229016	Vascular risk profile and white matter hyperintensity volume among Mexican Americans and non-Hispanic Whites: The HABLE study.	Alzheimers Dement (Amst)	King KS (2022)	HABLE	Cross sectional	Association of HbA1c and WMH	Age Sex Ethnicity Vascular risk factors	Greater vascular burden on Hispanic
15	35352569	Association of Brain Volumes and White Matter Injury With Race, Ethnicity, and Cardiovascular Risk Factors: The Multi-Ethnic Study of Atherosclerosis.	J Am Heart Assoc	Austin TR (2022)	MESA	Cross sectional	Association of race/ ethnicity and of cardiovascular risk factors	Age Sex Site BMI Smoking status Systolic blood pressure Diastolic blood pressure Hypertension medication use High-density lipoprotein Low-density lipoprotein Diabetes Estimated glomerular filtration rate Educational attainment Income Neighborhood socioeconomic status	Greater vascular and socioeconomic burden on African Americans
17	19926835	Blood pressure and white-matter disease progression in a biethnic cohort: Atherosclerosis Risk in Communities (ARIC) study.	Stroke	Gottesman RF (2010)	ARIC	Longitudinal	Association of WMH progression and BP.	Age Sex Race Body mass index from visit 3 Smoking status Diabetes (fasting glucose≥ 126 mg/dL at visit 3) Education (categorized <=8, 9–11, 12–13, 14–16, 17–20, or >=21 years) Prevalent coronary heart disease (visit 3)	Greater vascular burden on African Americans
22	18695055	Brain morphology in older African Americans, Caribbean Hispanics, and whites from northern Manhattan.	Arch Neurol	Brickman AM (2008)	WHICAP	Cross sectional	Association of age, sex, vascular disease with WMH across races.	Sex Ethnicity Self-reported vascular disease history	Greater vascular burden on African Americans
29	29648842	Ethnoracial differences in brain structure change and cognitive change.	Neuropsychology	Gavett BE (2018)	UCD Aging Diversity Cohort	Longitudinal	Associations of structural magnetic resonance imaging (MRI) and cognition in a diverse sample	Age Gender Education Ethno-racial group ApoE genotype	Greater vascular burden on Hispanic
31	28446647	Relationship between carotid arterial properties and cerebral white matter hyperintensities.	Neurology	Rundek T (2017)	NOMAS	Cross sectional	Association of large carotid diameter and WMH	Age Sex Educational Moderate alcohol use Smoking Moderate to heavy physical activity BMI Diabetes Low density lipoprotein Antihypertension medication Time from carotid ultrasound to MRI.	Greater vascular burden on African Americans and Hispanics
33	24203844	Effect of normal aging versus hypertension, abnormal body mass index, and diabetes mellitus on white matter hyperintensity volume.	Stroke	King KS (2014)	Dallas Heart Study	Cross sectional	Association of WMH and comorbidities	Gender Ethnicity Intracranial volume as estimated by FSL.	Greater vascular burden on African Americans

analysis, Writing – original draft. **Charles DeCarli:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors have no disclosures to this work.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.cccb.2024.100204.

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