Identifying neighbourhood and individual resilience profiles for cardiovascular health: a cross-sectional study of blacks living in the Atlanta metropolitan area

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ABSTRACT

Objective To simultaneously examine multiple individual-level neighbourhood perceptions and psychosocial characteristics and their relationships with cardiovascular health (CVH) among blacks.

Design Cross-sectional study.

Setting Subjects were recruited between 2016 and 2018 via convenience sampling.

Participants 385 Black men and women, age 30–70 living in the Atlanta metropolitan area (Georgia, USA).

Primary outcome measure Individual’s CVH was summarised as a composite score using American Heart Association’s Life’s Simple 7 (LS7) metrics.

Methods We implemented unsupervised learning (k-means) and supervised learning (Bayesian Dirichlet process clustering) to identify clusters based on 11 self-reported neighbourhood perception and psychosocial characteristics. We also performed principal component analysis to summarise neighbourhood perceptions and psychosocial variables and assess their associations with LS7 scores.

Results K-means and Bayesian clustering resulted in 4 and 5 clusters, respectively. Based on the posterior distributions, higher LS7 scores were associated with better neighbourhood perceptions and psychosocial characteristics, including neighbourhood safety, social cohesion, activities with neighbours, environmental mastery, purpose in life, resilient coping and no depression. Taken together, the first principal components of neighbourhood perceptions and psychosocial characteristics were associated with an increase of 0.07 (95% CI −0.17 to 0.31) and 0.31 (95% CI 0.06 to 0.55) in LS7 score, respectively, after accounting for age, sex, household income and education level.

Conclusion Both neighbourhood perception and psychosocial domains were related to CVH, but individual psychosocial characteristics appeared to contribute to CVH most. Approaches that acknowledge the importance of factors in both domains may prove most beneficial for enhancing resilience and promoting CVH among black communities.

Strengths and limitations of this study

- The study focused on risk and resilience heterogeneity within blacks, an at-risk population.
- We used multivariate cluster analysis to efficiently investigate 11 neighbourhood perception and psychosocial variables related to cardiovascular health as opposed to treating them as separate exposures in previous studies.
- This is a single site study that used convenience sampling, so the results may not be generalisable to the target study population.

Despite the remarkable decline in cardiovascular disease (CVD) mortality among all major racial and ethnic groups in the USA during the past four decades,1 black-white disparities in the rate of decline in CVD mortality and cardiovascular health (CVH) remain persistent across different age groups.2–4 Compared with other ethnic groups, blacks have the highest CVD burden and lowest rate of mortality decline.5–6 Specifically, blacks have a higher prevalence of many CVD risk factors, including obesity, hypertension, diabetes and dyslipidaemia.7,8 In addition to traditional CVD risk factors, other underlying mechanisms, such as neighbourhood characteristics, psychosocial stress, individual perspectives, socioeconomic status, are likely to be responsible for the increased risk for CVD in Blacks.9–12 The aggregation of these traditional and non-traditional risk factors, including social determinants, likely contributes to a higher CVD burden among Blacks.13

Research on CVD in blacks has focused almost exclusively on their excess risk for poor CVH, relative to other racial/ethnic...
groups. However, this ignores the fact that there is considerable heterogeneity within the black population, such that some black individuals have better CVH profiles than others. Unfortunately, limited effort has been focused on examining those factors that might promote ‘resilience’ in this at-risk population. Resilience has been defined as the ‘ability of living systems to successfully maintain or return to homoeostasis’ in response to a range of challenges, including those that are ‘individual, social, societal or environmental’. In the context of CVH research, black ‘race’ often exposes individuals to a range of multifactorial challenges, at multiple levels, that are believed to drive their excess rates of disease. Similarly, these resilience factors are also likely to be multifactorial, operating at the level of both individuals and their environmental/neighbourhood context. There is a growing body of evidence that individual psychosocial characteristics may as well as their neighbourhood perceptions may be important determinants of CVH. For instance, studies have identified an association between less depressive symptoms and better CVH profiles, including smoking and blood pressure control. CVH studies focusing on other psychosocial health measures in blacks remain limited. A few studies demonstrated that more optimistic individuals engage in more CVH behaviours, and that purpose in life and mastery is associated with a reduced risk for mortality and CVD events. On the other hand, several studies have investigated the role of neighbourhood environments in CVH using community samples. An in-depth investigation of a comprehensive set of candidate factors that potentially confer resilience to poor CVD outcomes in Blacks is essential to develop recommendations for targeted intervention strategies to improve their CVH.

One main challenge in population-based and observational research is to interrogate CVH profiles in the context of multidimensional (risk and resilient) exposure factors. The inter-correlated nature of exposure factors complicates the task to identify their combined effect on CVH outcomes. In traditional analysis with multiple exposure factors, data are frequently analysed univariately to determine associations with the outcome. These tests of association ignore the potential correlations among the exposure factors, do not account for their effects simultaneously, and often have low power to detect significant effects after multiple testing adjustment. In addition, each exposure factor may only account for a small proportion of variability in the outcome. To bypass these issues, clustering and classification techniques in machine learning have become popular given their ability to handle multiple exposure variables and to detect otherwise unappreciated grouping patterns.

The Morehouse-Emory Cardiovascular (MECA) Center for Health Equity study has identified neighbourhoods with vastly different rates of premature cardiovascular events among Blacks in the metropolitan Atlanta area. The study recruited a cohort of Black residents living in Atlanta and found that individuals living in neighbourhoods with lower cardiovascular event rates reported better neighbourhood characteristics and more positive psychosocial characteristics. This study builds off of these findings in another Atlanta based sample to examine the clustered patterns of self-reported neighbourhood perceptions and psychosocial characteristics and whether the clusters of characteristics are associated with individual-level CVH profile as measured by Life’s Simple 7 (LS7) score. Identifying patterns or clusters of important individual-level factors that correspond to high LS7 scores may provide a starting point for promoting CVH among blacks.

**METHODS**

**Patient and public involvement**

The development of the research question and outcome measures were not informed by study participants’ priorities, experience or preferences. The participants were not involved in the design, recruitment and conduct of the study. The results will be disseminated to study participants through publications and school websites.

**Study design and subjects**

This is a cross-sectional study design involving secondary analysis of data from the MECA study. A total of 400 adults living in the greater Atlanta region, with the age range of 30–70, who self-identified as black or African American were recruited between 2016 and 2018 via convenience sampling. The subjects were recruited by flyers, school’s website announcements, or family and friend’s referrals. The exclusion criteria included history of CVD (eg, myocardial infarction, congestive heart failure, cerebrovascular accidents, coronary artery disease, peripheral arterial disease, atrial fibrillation and cardiomyopathies), HIV, lupus, cancer, substance abuse (alcohol or drug), psychiatric illness, pregnant or lactating females, and inability to participate in increased physical activity. The exclusion criteria were set up due to an opportunity to participate in a lifestyle intervention trial in the original study (ClinicalTrials.gov Identifier: NCT03308812). Once enrolled, each study participant visited the research laboratory for physical examination, blood draw and completing survey questionnaires at either Emory University or Morehouse School of Medicine (Atlanta, Georgia, USA). Blood pressure and anthropometric measurements were recorded. All blood draws were performed after 12-hour fasting. In the survey, demographic information, residential address, medical history and socioeconomic status (income, education, employment and marital status) were collected. In addition, data on diet and exercise as well as preselected potential risk and resilience factors were obtained (details below). All study subjects provided written informed consents.

**LS7 Scores**

The ‘LS7’ concept focuses on primordial prevention with the goal of improving population’s CVH through changes
in lifestyle to ultimately lower the disease risk. Given that examining individual metrics separately is not efficient (due to multiple testing issues) and only provides marginal information rather than an overall summary of CVH, the American Heart Association (https://mlc.heart.org) has created a composite score by assigning a value to each metric and adding up the scores.45–50 Specifically, an ideal CVH profile involves ideal physical activity (≥150 or 75 min/week of moderate-intensity or vigorous-intensity exercise, respectively), total cholesterol (<200 mg/dL), blood pressure (<120/80 mm Hg), fasting glucose (<100 mg/dL), body mass index (<25 kg/m²), non-smoking, as well as healthy diet (defined by fruit/vegetable, whole grain, fish, sugar and salt intake).48 The definitions of ideal, intermediate and poor level for each metric are provided in online supplemental material based on ‘My Life Check’, a health assessment and improvement tool (https://mlc.heart.org). We assigned 2, 1 and 0 points to ideal, intermediate and poor level, respectively, for each metric and obtained a LS7 score ranging between 0 and 14. A higher score indicates better CVH.

**Individual-level, self-reported factors for clustering**

A total of 11 variables associated with neighbourhood perceptions and individual psychosocial characteristics were considered in the study (see online supplemental materials). Five neighbourhood perceptions were assessed, including aesthetic quality, walking environment, safety, social cohesion and activities with neighbours.51 Five neighbourhood perceptions were considered in the study (see online supplemental materials). The definitions of ideal, intermediate and poor level for each metric are provided in online supplemental material based on ‘My Life Check’, a health assessment and improvement tool (https://mlc.heart.org). We assigned 2, 1 and 0 points to ideal, intermediate and poor level, respectively, for each metric and obtained a LS7 score ranging between 0 and 14. A higher score indicates better CVH.

**Statistical analysis**

Out of the 400 recruited subjects, 395 were successfully enrolled in the study. Among them, six did not have LS7 scores due to skipping blood draws, and four omitted at least two questionnaires entirely, which resulted in an analysis sample size of 385. Continuous variables for subject characteristics were summarised as means (±SD) or as median (25th and 75th quartiles) while categorical variables were reported as frequency counts and proportions (percentages), as appropriate. Once the clusters were identified by k-means, analysis of variance was applied to compare LS7 scores among the k-means clusters followed by Tukey’s honestly significant difference post hoc tests for pairwise comparisons. Next, linear regression was used to regress LS7 score on the k-means clusters with adjustment for age, sex, annual household income per person, and education level as these are known to be associated with CVH. Participants identified their annual household income from eight categories with various ranges of income (eg, US$10 000–US$15 000, US$15 000–US$20 000). A crude representation of annual income per person was configured by dividing the
median of a given income bracket by the household size. Participants selected their highest education level from five categories that were later collapsed into three categories for analysis: college graduate, some college or technical school and high school graduate or below.

To evaluate the contributions of neighbourhood perception domain and individual psychosocial domain to individual’s CVH, separate principal component (PC) analyses were applied to the five neighbourhood perception variables and the six psychosocial variables, respectively. We then extracted the first PC (PC1) for each domain, namely, PC1_nbh and PC1_ind. A linear regression was used to assess the association between LS7 score and PC1_nbh and PC1_ind with adjustment of age, sex, income, and education (defined above). All statistical analyses were performed using R V.3.3.1. Two-sided tests were considered and p<0.05 was deemed statistically significant.

RESULTS

Participant characteristics
Table 1 shows the characteristics of the 385 participants, with a mean age of 52.7±10.3 years and 60.8% females. The mean LS7 score was 7.99±2.19. Overall, 176 (46%), 75 (20%) and 85 (22%) reported to have hypertension, diabetes and dyslipidaemia, respectively. About one-third (34%) had a college degree, 37% had some college education whereas 28% had high school degree or below. Additionally, 47% reported an annual household income of less than US$25,000 with 23% less than US$10,000. The median income per person in the household was US$12,500 (IQR US$5,000—US$21,250).

Overall neighbourhood perception and psychosocial health profile groups associated with LS7 via Bayesian Dirichlet process clustering

We applied profile regression via Bayesian Dirichlet process clustering to classify participants based on the 11 variables (summary scores from self-reported questionnaires). Table 1 shows the five identified clusters with the following sample sizes: 27 (7%), 71 (18%), 129 (34%), 108 (28%) and 50 (13%). Their mean LS7 scores were 4.26, 5.58, 7.47, 9.44 and 11.64, respectively. Cluster 5 (with the highest LS7 score) consisted of younger subjects (4–10 years younger on average), less females (50% vs ~60% in other clusters) and higher income and education levels, compared with other clusters. Age and sex distributions in cluster 1 (with the lowest LS7 score) did not appear to be different from other clusters; however, income and education levels were appreciably lower.

Figure 1 displays the posterior distributions of the neighbourhood perception and individual psychosocial scores corresponding to each cluster. Cluster 1 exhibited consistently lower scores compared with other clusters. Cluster 5 exhibited consistently highest scores (except Everyday Discrimination) across all the clusters. Specifically, scores in neighbourhood safety, social cohesion, activities with neighbours, environmental mastery, purpose in life and resilient coping were substantially higher in cluster 5 compared with the rest according to the 90% credible intervals. The majority of the subjects (80%) in clusters 2, 3 and 4 demonstrated intermediate scores in both the neighbourhood perception and psychosocial domains.

Overall neighbourhood perception and psychosocial health clusters derived from k-means

The optimal number of k-means clusters was 4. Figure 2 shows the mean scores of the 11 variables for each k-means cluster. Cluster 1 (n=112) exhibited consistently higher scores, on average, for both the neighbourhood perception and individual psychosocial health domains. Cluster 2 (n=41) demonstrated the lowest scores for variables belonging to the neighbourhood perception domain. Cluster 3 (n=147) had an intermediate mean score for each variable in the neighbourhood perception domain. The scores in the psychosocial health domain, on the other hand, were almost as high as those in cluster 1. Cluster 4 (n=85) also had an average score for each variable in the neighbourhood perception domain but overall exhibited the lowest scores in the individual psychosocial health domain.

Association between the k-means clusters and LS7

Figure 3 illustrates the distributions of LS7 score among the 4 k-means clusters. The LS7 score was significantly different across the four clusters (p=0.006), and the Tukey’s post hoc test indicated a significant difference of 0.91 (95% CI 0.11 to 1.71) in LS7 score between cluster 1 and cluster 4 (p=0.019). Table 2 shows the estimated difference in LS7 score among the clusters. The mean LS7 score for cluster 2 and cluster 4 were estimated to be 0.79 (95% CI 0.01 to 1.58) and 0.67 (95% CI 0.05 to 1.29) lower than of cluster 1 after adjusting for age, sex, income and education. Younger age and having a college degree were found to be associated with a higher LS7 score.

Contributions of neighbourhood perceptions and psychosocial characteristics to LS7

On applying PC analysis, PC1_nbh and PC1_ind explained 56% and 55% variability of the data, respectively. Table 3 displays the loadings for PC1_nbh and PC1_ind, which suggest that all the scores contributed to PC1 fairly evenly. Table 4 shows the estimated differences in LS7 score corresponding to 1 SD increase in PC1_nbh and PC1_ind, adjusting for age, sex, education and income. When both PC1_nbh and PC1_ind were included in the same model, PC1_ind but not PC1_nbh was significantly associated with LS7 score. A 1 SD increase in PC1_ind is associated with an estimated increase of 0.31 (95% CI 0.06 to 0.55) in LS7 score.

DISCUSSION

We used existing clustering methods to integrate multiple variables related to neighbourhood perceptions and psychosocial characteristics in the analysis of overall CVH. These approaches allow for the
|                      | Cluster 1 (n=27)       | Cluster 2 (n=71)       | Cluster 3 (n=129)      | Cluster 4 (n=108)      | Cluster 5 (n=50)       | All (n=385)            |
|----------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| Life’s Simple 7 score| 4.26 (0.66)            | 5.58 (0.50)            | 7.47 (0.52)            | 9.44 (0.54)            | 11.64 (0.69)           | 7.99 (2.19)            |
| Age (years)          | 53.8 (8.84)            | 56.1 (8.00)            | 54.7 (9.30)            | 50.8 (10.4)            | 46.3 (12.1)            | 52.7 (10.3)            |
| Sex (female)         | 16 (59.3%)             | 47 (66.2%)             | 81 (62.8%)             | 65 (60.2%)             | 25 (50.0%)             | 234 (60.8%)            |
| Annual income (USD per person)* | $5000 (2396, 9375) | $12 500 (5625, 21 250) | $11 900 (5000, 22 500) | $14 150 (5625, 21 250) | $14 400 (7500, 21 250) | $12 500 (5000, 21 250) |
| Education*           | High school and under  | 15 (55.6%)             | 19 (26.8%)             | 37 (28.7%)             | 28 (25.9%)             | 10 (20.0%)             | 109 (28.3%)            |
|                      | Some college or technical | 11 (40.7%)             | 25 (35.2%)             | 50 (38.8%)             | 40 (37.0%)             | 18 (36.0%)             | 144 (37.4%)            |
|                      | College degree         | 1 (3.7%)               | 27 (38.0%)             | 41 (31.8%)             | 40 (37.0%)             | 22 (44.0%)             | 131 (34.0%)            |
| BMI (kg/m²)          | 36.8 (8.58)            | 36.4 (7.35)            | 34.4 (8.24)            | 30.9 (7.49)            | 25.7 (4.61)            | 32.8 (8.22)            |
| Physical activity*   | None                   | 9 (33.3%)              | 9 (12.7%)              | 11 (8.5%)              | 3 (2.8%)               | 0 (0%)                 | 32 (8.3%)              |
|                      | Some                   | 13 (48.1%)             | 33 (46.5%)             | 47 (36.4%)             | 29 (26.9%)             | 7 (14.0%)              | 129 (33.5%)            |
|                      | Meets AHA recommendation† | 5 (18.5%)             | 29 (40.8%)             | 71 (55.0%)             | 76 (70.4%)             | 43 (86.0%)             | 224 (58.2%)            |
| Systolic blood pressure (mm Hg) | 137 (16)    | 141 (21)               | 133 (19)               | 125 (18)               | 119 (15)               | 131 (20)               |
| Diastolic blood pressure (mm Hg) | 85 (11)    | 85 (13)               | 83 (12)               | 77 (10)               | 72 (9)               | 80 (12)               |
| Fasting glucose (mg/dL) | 108 (95.5, 133.5) | 104 (95, 126.5) | 92 (87, 100) | 88.0 (84, 94) | 86.0 (82, 91) | 92 (86, 102) |
| Cholesterol (mg/dL) | 199 (41.4)           | 207 (46.9)             | 197 (39.6)             | 184 (33.4)             | 173 (27.7)             | 192 (39.6)             |
| Hypertension         | 25 (92.6%)            | 53 (74.6%)             | 69 (53.5%)             | 25 (23.1%)             | 4 (8.0%)               | 176 (45.7%)            |
| Diabetes             | 16 (59.3%)            | 30 (42.3%)             | 25 (19.4%)             | 4 (3.7%)               | 0 (0%)                 | 75 (19.5%)             |
| Dyslipidaemia        | 12 (44.4%)            | 22 (31.0%)             | 40 (31.0%)             | 10 (8.3%)              | 1 (2.0%)               | 85 (22.1%)             |
| Smoking history*     | Current smoker        | 16 (59.3%)             | 23 (32.4%)             | 36 (27.9%)             | 16 (14.8%)             | 1 (2.0%)               | 92 (23.9%)             |
|                      | Quit smoking ≤12 months | 1 (3.7%)             | 5 (7.0%)               | 6 (4.7%)               | 4 (3.7%)               | 1 (2.0%)               | 17 (4.4%)              |
|                      | Never smoked or quit smoking >12 months | 10 (37.0%) | 43 (60.6%) | 87 (67.4%) | 88 (81.5%) | 48 (86.0%) | 276 (71.7%) |
| Diet (no of non-ideal components)* | 4.30 (1.14) | 4.01 (1.29) | 3.84 (1.37) | 3.73 (1.55) | 3.32 (1.36) | 3.81 (1.41) |

Mean (SD), median (lower quartile, upper quartile) or frequency count (percentage) are presented.

*Self-reported measures.
†At least 150 min of moderate aerobic exercise or 75 min of vigorous exercise (or a combination of both) per week.
AHA, American Heart Association; BMI, body mass index.
identification of underlying grouping and the development of potential research hypotheses. Additionally, we performed PC analysis to summarise neighbourhood perception and individual psychosocial health variables by retaining the first PC for each domain. Overall, the results indicate that both domains are related to CVH among Blacks. Specifically, higher LS7 scores were observed among those with better neighbourhood perceptions and psychosocial profiles, including neighbourhood safety, social cohesion, activities with neighbours, environmental mastery, purpose in life, resilient coping and no depression.

The Bayesian Dirichlet process clustering produced the posterior distributions of the neighbourhood perception and psychosocial variables for the five identified, representative clusters linking to LS7 scores. This approach allows users to perform a comprehensive examination of the 11 variables, to evaluate the likelihood of each factor’s contribution to high or low LS7 scores, and to compare the similarity and dissimilarity measures among the clusters. All the scores, except everyday discrimination, show a consistent increasing
The results suggest that both domains are important to CVH. Notably, only PC1ind was significantly associated with LS7 score. Our findings are consistent with the PC analysis of previous studies that when both factors were considered simultaneously, cluster 3 had a significantly higher LS7 score compared to cluster 4.

After adjusting for age, sex, income and education, we found that the LS7 scores (ie, clusters 3 vs 4) and vice versa (ie, clusters 1 vs 3) were significantly different. This is consistent with the Jackson Heart Study.19

On the other hand, k-means seeks to define homogeneous groups among the 11 variables of interest without connecting the outcome variable. The resulting 4 k-means clusters allow for the investigation of individual psychosocial characteristics (high vs low scores) with similar neighbourhood perception scores (ie, clusters 3 vs 4) and vice versa (ie, clusters 1 vs 3). After adjusting for age, sex, income and education, we found that cluster 3 had a significantly higher LS7 score compared with cluster 4. The results are consistent with the PC analysis findings that when both factors were considered simultaneously, only PC1ind was significantly associated with LS7 score. The results suggest that both domains are important to CVH with the psychosocial health domain being more dominant.

We present a comprehensive investigation of multiple dimensions in both the neighbourhood perception and psychosocial domains in one study rather than inspecting one single 'exposure' and CVH at a time. Our study provides a unique opportunity to evaluate the link between neighbourhoods, psychosocial factors and achieving ideal CVH, which is critical for Blacks given their higher CVD burden. However, our study has a number of limitations. The study participants with 60% being female and nearly 50% being low income were recruited using convenience sampling, which is critical for Blacks given their higher CVD burden.

In addition, cluster uncertainty is an issue when using clustering and classification methods. A comprehensive validation procedure is desired and would be meaningful with a much larger-scaled study, but it is beyond the scope of our current exploratory study with a modest sample size. Lastly, we are not able to determine the directionality of association as to whether modifying psychosocial factors would lead to behaviour changes related to CVH given a cross-sectional study design. It is possible that people with healthier psychological characteristics are more likely to engage in CVH activities and CVH activities, in turn, are likely to foster better psychosocial health and neighbourhood perceptions.

**CONCLUSIONS**

We demonstrated the use of clustering methods to translate multiple questionnaire scores to one grouping variable for the analysis of CVH, which provides a useful characterisation of overall neighbourhood perception and psychosocial health profiles and avoids investigating

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**Table 2** Estimated difference in LS7 score among clusters defined by k-means with adjustment of age, sex, education and income

| Cluster 2 vs 1 | Estimated difference in LS7 (95% CI) | P value |
|---------------|-------------------------------------|--------|
| Cluster 3 vs 1 | −0.79 (−1.58 to −0.01)              | 0.047  |
| Cluster 4 vs 1 | −0.13 (−0.66 to 0.40)               | 0.64   |
| Age (year)     | −0.67 (−1.29 to −0.05)              | 0.033  |
| Sex (male vs female) | 0.38 (−0.06 to 0.83) | 0.093 |

**Table 3** Loadings for the first principal components of neighbourhood perception (PC1nbh) and individual psychosocial health scores (PC1ind)

| Loadings for PC1nbh | Loadings for PC1ind |
|---------------------|--------------------|
| Cohesion            | 0.4981             |
| Safety              | 0.4698             |
| Walking environment | 0.4659             |
| Aesthetic quality   | 0.4368             |
| Activities with neighbours | 0.3512 | 0.2549 |
| Everyday discrimination |                |

**Table 4** Association between LS7 score and the first principal components (PC1) of neighbourhood perception and individual psychosocial health scores with adjustment of age, sex, education and income

| Estimated difference in LS7 (95% CI) | P value |
|-------------------------------------|--------|
| PC1nb (per SD)                      | 0.07 (−0.17 to 0.31) | 0.56 |
| PC1ind (per SD)                     | 0.31 (0.06 to 0.55)  | 0.013 |
| Age (year)                          | −0.06 (−0.08 to −0.04) | <0.001 |
| Sex (male vs female)                | 0.43 (−0.03 to 0.88) | 0.064 |
| Education                           | Some college: 0.27 (−0.29 to 0.83) | 0.35 |
| College graduate                    | 0.83 (0.22 to 1.45)  | 0.008 |
| Annual income (US$5000/person)      | 0.01 (−0.07 to 0.09) | 0.80 |

LS7, Life’s Simple 7.
individual variables separately. Our findings suggest that CVH profiles are potentially affected by both neighbourhood perceptions (ie, neighbourhood safety, social cohesion and activities with neighbours) and psychosocial factors (environmental mastery, purpose in life, resilient coping and no depression). This suggests that policies aimed at improving the ability of black adults to support and gather safely with others in their neighbourhood (eg, crime reduction initiatives, support for community gathering locations and other community services) might ultimately enhance CVH at the neighbourhood level. At the same time, psychosocial treatments that focus on improving feelings of mastery, providing a sense of purpose, improving coping and reducing depression might enhance CVH at the individual level. However, approaches that acknowledge the importance of factors at both levels might prove most beneficial for enhancing resilience and promoting CVH among black communities.

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Contributors
YK designed the analytic strategies, analysed the data, interpreted the results and wrote the manuscript. JS helped conduct literature review, data analysis and drafting the result section. JHK and MT helped with the implementation of the main study, including data quality assurance. MM, HT, AO, MS and VV reviewed the paper and provided constructive feedback. AO and HT are the centre grant PIs. PB and TL are the project PIs. All of the authors reviewed the manuscript, shared comments and edited the manuscript.

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Competing interests
None declared.

Patient consent for publication
Not required.

Ethics approval
Emory University and Morehouse School of Medicine IRB have approved this study. The Emory IRB approval number is 83 584. Morehouse IRB approvals relevant to this study are listed in the following: 809 392–1 (Clinical) and 790 389–2 (Population).

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Data availability statement
Data are available on reasonable request. The analysis data are available on request through the corresponding author with approval from the study principal investigators. Investigators who are interested in collaborative work are encouraged to contact PB (pbhaltrus@msm.edu) and TL (tene.l@emory.edu).

Supplemental material
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REFERENCES
1 Mensah GA, Wei GS, Sorlie PD, et al. Decline in cardiovascular mortality: possible causes and implications. Circ Res 2017;120:366–80.
2 Jolly S, Vittinghoff E, Chattopadhyay A, et al. Higher cardiovascular disease prevalence and mortality among younger blacks compared to whites. Am J Med 2010;123:811–8.
3 Brown AF, Liang L-J, Vassar SD, et al. Trends in racial/ethnic and Nativity disparities in cardiovascular health among adults without prevalent cardiovascular disease in the United States, 1998 to 2014. Ann Intern Med 2018;168:168.
4 Brown AF, Liang L-J, Vassar SD. Trends in Racial/Ethnic/Nativity disparities in cardiovascular health among adults without prevalent cardiovascular disease in the United States, 1988-2010. J Gen Intern Med 2017;32.
5 Global Burden of Cardiovascular Diseases Collaboration, Roth GA, Johnson CO, et al. The burden of cardiovascular diseases among US states, 1990-2016. JAMA Cardiol 2018;3:375–89.
6 Bonow RO, Grant AO, Jacobs AK. The cardiovascular state of the Union: confronting healthcare disparities. Circulation 2005;111:1205–7.
7 Howard G, Safford MM, Moy CS, et al. Racial differences in the incidence of cardiovascular risk factors in older black and white adults. J Am Geriatr Soc 2017;65:83–90.
8 Hajjar I, Kotchen TA. Trends in prevalence, awareness, treatment, and control of hypertension in the United States, 1988-2000. JAMA 2003;290:199–206.
9 Farmer MM, Ferraro KF. Are racial disparities in health conditional on socioeconomic status? Soc Sci Med 2005;60:191–204.
10 Saab KR, Kendrick J, Yacheta JM, et al. New insights on the risk for cardiovascular disease in African Americans: the role of added sugars. J Am Soc Nephrol 2015;26:247–57.
11 Zenk SN, Schulz AJ, Hollis-Neely T, et al. Fruit and vegetable intake in African Americans income and store characteristics. Am J Prev Med 2005;29:1–9.
12 Kronish IM, Carson AP, Davidson KW, et al. Depressive symptoms and cardiovascular health by the American heart association’s definition in the reasons for geographic and racial differences in stroke (regards) study. PLoS One 2012;7:e52771.
13 Mensah GA, Mokdad AH, Ford ES, et al. State of disparities in cardiovascular health in the United States. Circulation 2005;111:1233–41.
14 Enhancing resilience for cardiovascular health and wellness, 2018. Available: https://www.nhlbi.nih.gov/events/2018/enhancing-resilience-cardiovascular-health-and-wellness [Accessed 1 Apr 2021].
15 Vaccarino V, McClure C, Johnson BD, et al. Depression, the metabolic syndrome and cardiovascular risk. Psychosom Med 2008;70:40–8.
16 Vaccarino V, Johnson BD, Sheps DS, et al. Depression, inflammation, and incident cardiovascular disease in women with suspected coronary ischemia: the National heart, lung, and blood Institute-sponsored wise study. J Am Coll Cardiol 2007;50:2044–50.
17 Ferraro KF, Kim S. Health benefits of religion among black and white older adults? race, religiosity, and C-reactive protein. Soc Sci Med 2014;120:92–9.
18 Boyle PA, Barnes LL, Buchman AS, et al. Purpose in life is associated with mortality among community-dwelling older persons. Psychosom Med 2009;71:574–9.
19 Sims M, Diez-Roux AV, Dudley A, et al. Perceived discrimination and hypertension among African Americans in the Jackson heart study. Am J Public Health 2012;102 Suppl 2:5258–65.
20 Lewis TT, Aiello AE, Leurgans S, et al. Self-Reported experiences of everyday discrimination are associated with elevated C-reactive
protein levels in older African-American adults. Brain Behav Immun 2010;24:438–43.

21 Lewis TT, Barnes LL, Bienias JL, et al. Perceived discrimination and blood pressure in older African American and white adults. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences 2009;64A:1002–8.

22 Lewis TT, Everson-Rose SA, Powell LH, et al. Chronic exposure to everyday discrimination and coronary artery calcification in African-American women: the Swan heart study. Psychosom Med 2006;68:362–6.

23 Unger E, Diez-Roux AV, Lloyd-Jones DM, et al. Association of neighborhood characteristics with cardiovascular health in the multi-ethnic study of atherosclerosis. Circ Cardiovasc Qual Outcomes 2014;7:524–31.

24 Clark CR, Ommerborn MJ, Hickson DA, et al. Neighborhood disadvantage, neighborhood safety and cardiometabolic risk factors in African Americans: biosocial associations in the Jackson heart study. PLoS One 2013;8:e63254.

25 Dailey AB, Kasl SV, Holford TR, et al. Neighborhood- and individual-level socioeconomic variation in perceptions of racial discrimination. Ethn Health 2010;15:145–63.

26 Sims M, Lipford KJ, Patel N, et al. Psychosocial factors and behaviors in African Americans: the Jackson heart study. Am J Prev Med 2017;52:342–51.

27 Ford CD, Sims M, Higginbotham JC, et al. Psychosocial factors are associated with blood pressure progression among African Americans in the Jackson heart study. Am J Hypertens 2016;29:913–24.

28 Boehm JK, Chen Y, Koga H, et al. Is optimism associated with healthier Cardiovascular-Related behavior? meta-analyses of 3 health behaviors. Circ Res 2018;122:1119–34.

29 Cohen R, Bavishi C, Rozanski A. Purpose in life and its relationship to all-cause mortality and cardiovascular events: a meta-analysis. Psychosom Med 2016;78:122–33.

30 Sutte PG, Wainwright NWJ, Luben R, et al. Mastery is associated with cardiovascular disease mortality in men and women at apparently low risk. Health Psychol 2010;29:412–20.

31 Mayne SL, Moore KA, Powell-Wiley TM, et al. Longitudinal associations of neighborhood crime and perceived safety with blood pressure: the multi-ethnic study of atherosclerosis (MESA). Am J Hypertens 2018;31:1024–32.

32 Wing JJ, August E, Adar SD, et al. Change in neighborhood characteristics and change in coronary artery calcium: a longitudinal investigation in the MESA (multi-ethnic study of atherosclerosis) cohort. Circulation 2016;134:504–13.

33 Christine PJ, Auchincloss AH, Bertoni AG. Longitudinal associations between neighborhood physical and social environments and incident type 2 diabetes mellitus: the multi-ethnic study of atherosclerosis (MESA). JAMA Intern Med 2015;175:1311–20.

34 Tomey K, Diez Roux AV, Clarke P, et al. Associations between neighborhood characteristics and self-rated health: a cross-sectional investigation in the multi-ethnic study of atherosclerosis (MESA) cohort. Health Place 2013;24:267–74.

35 Auchincloss AH, Diez Roux AV, Mujahid MS, et al. Neighborhood resources for physical activity and healthy foods and incidence of type 2 diabetes mellitus: the multi-ethnic study of atherosclerosis. Arch Intern Med 2009;169:1686–704.

36 Ranchod YK, Diez Roux AV, Evenson KR, et al. Longitudinal associations between neighborhood recreational facilities and change in recreational physical activity in the multi-ethnic study of atherosclerosis, 2000-2007. Am J Epidemiol 2014;179:584–94.

37 Ranchod YK, Diez Roux AV, Evenson KR, et al. Longitudinal associations between neighborhood recreational facilities and change in recreational physical activity in the multi-ethnic study of atherosclerosis, 2000-2007. Am J Epidemiol 2014;179:335–43.

38 Brewer LC, Redmond N, Slussper JP, et al. Stress and achievement of cardiovascular health metrics: the American heart association life’s simple 7 in blacks of the Jackson heart study. J Am Heart Assoc 2018;7. doi:10.1161/JAHA.118.008855. [Epub ahead of print: 05 Jul 2018].

39 Reeves RR, Adams CE, Dubbert PM, et al. Are religiosity and spirituality associated with obesity among African Americans in the southeastern United States (the Jackson heart study)? J Relig Health 2012;51:32–48.

40 Auchincloss AH, Mujahid MS, Shen M, et al. Neighborhood health-promoting resources and obesity risk (the multi-ethnic study of atherosclerosis). Obesity 2013;21:621–8.

41 Kim JH, Lewis TT, Topel ML, et al. Identification of resilient and at-risk neighborhoods for cardiovascular disease among black residents: the Morehouse-Emory cardiovascular (Meca) center for health equity study. Prev Chronic Dis 2019;16:E57.

42 Topel ML, Kim JH, Mujahid MS, et al. Individual characteristics of resilience are associated with Lower-Than-Expected neighborhood rates of cardiovascular disease in blacks: results from the Morehouse-Emory cardiovascular (Meca) center for health equity study. J Am Heart Assoc 2019;8:e011633.

43 Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American heart association’s strategic impact goal through 2020 and beyond. Circulation 2010;121:586–613.

44 AI Mheid I, Kelli HM, Ko Yi-An, et al. Effects of a Health-Partner intervention on cardiovascular risk. J Am Heart Assoc 2016;5.

45 Effoe VS, Carnethon MR, Echoufo-Otouegji JB, et al. The American heart association ideal cardiovascular health and incident type 2 diabetes mellitus among blacks: the Jackson heart study. J Am Heart Assoc 2017;6. doi:10.1161/JAHA.116.005008. [Epub ahead of print: 21 Jun 2017].

46 Gaye B, Canonico M, Perier M-C, et al. Ideal cardiovascular health, mortality, and vascular events in elderly subjects: the Three-City Study. J Am Coll Cardiol 2017;69:3015–26.

47 Kulshreshtha A, Vaccarino V, Goyal A, et al. Family history of stroke and cardiovascular health in a national cohort. J Stroke Cerebrovasc Dis 2015;24:447–54.

48 Speno N, Chen Y, Guida JL, et al. Positive childhood experiences and ideal cardiovascular health in midlife: associations and mediators. Prev Med 2017;97:72–7.

49 Folsom AR, Shah AM, Lutsy PL, et al. American heart association’s life’s simple 7 avoiding heart failure and preserving cardiac structure and function. Am J Med 2015;128:e970–6.

50 Desai CS, Ning H, Liu K, et al. Cardiovascular health in young adulthood and association with left ventricular structure and function later in life: the coronary artery risk development in young adults study. J Am Soc Echocardiogr 2015;28:1452–61.

51 Mujahid MS, Diez Roux AV, Morenoff JD, et al. Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. Am J Epidemiol 2007;165:858–67.

52 Kiefe CI, Williams OD, Bild DE, et al. Regional disparities in the incidence of elevated blood pressure among young adults: the cardia study. Circulation 1997;96:1082–8.

53 Scheier MF, Carver CS. Optimism, coping, and health: assessment and implications of generalized outcome expectancies. Health Psychol 1985;4:219–47.

54 Scheier MF, Carver CS, Bridges MW. Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): a reevaluation of the life orientation test. J Pers Soc Psychol 1994;67:1063–78.

55 Ryff CD. Happiness is everything, or is it? explorations on the meaning of psychological well-being. J Pers Soc Psychol 1989;57:1069–81.

56 Ryff CD, Keyes CL. The structure of psychological well-being revisited. J Pers Soc Psychol 1995;69:719–27.

57 Campbell-Sills L, Stein MB. Psychometric analysis and refinement of the Connor-Davidson resilience scale (CD-RISC): validation of a 10-item measure of resilience. J Trauma Stress 2007;20:1019–28.

58 Beck AT, Ward CH, Mendelson M, et al. An inventory for measuring depression. Arch Gen Psychiatry 1961;4:561–71.

59 Molfot J, Papathomas M, Jarrett R, et al. Bayesian profile regression with an application to the National survey of children’s health. Bioinformatics 2010;11:484–98.

60 Liverani S, Hastej DI, Azizi L, et al. Premium: an R package for profile regression mixture models using Dirichlet processes. J Stat Softw 2015;64:1–30.

61 Jain AK. Data clustering: 50 years beyond k-means. Pattern Recognit Lett 2010;31:651–66.

62 Jain AK, Dubes RC. Algorithms for clustering data. Englewood Cliffs, N.J: Prentice Hall, 1988. 