

BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

Neighbourhood Context and Cumulative Biological Risk in a Developing Country: Evidence from the Jamaica Health and Lifestyle Survey 2008

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-021952
Article Type:	Research
Date Submitted by the Author:	26-Jan-2018
Complete List of Authors:	Cunningham-Myrie, Colette; University of the West Indies at Mona Faculty of Medical Sciences, Community Health and Psychiatry Mabile, Emily; Louisiana Office of Public Health, Bureau of Family Health Govia, Ishtar; University of the West Indies, Caribbean Institute for Health Research Younger, Novie; University of the West Indies, Caribbean Institute for Health Research Tulloch-Reid, Marshall; The University of the West Indies , Caribbean Institute for Health Research McFarlane, Shelly ; University of the West Indies, Caribbean Institute for Health Research Francis, Damian; University of the West Indies, Caribbean Institute for Health Research Gordon-Strachan, Georgiana; University of the West Indies, Caribbean Institute for Health Research Wilks, Rainford; University of the West Indies, Caribbean Institute for Health Research Greene, Lisa-Gaye; University of the West Indies, Mona GeoInformatics Institute Lyew-Ayee, Parris; University of the West Indies, Mona GeoInformatics Institute Theall, Katherine; Tulane University, Global Community Health and Behavioral Sciences
Keywords:	developing country, cumulative biological risk, women, neighbourhoods

SCHOLARONE™
Manuscripts

1
2
3 **Neighbourhood Context and Cumulative Biological Risk in a Developing Country:**
4 **Evidence from the Jamaica Health and Lifestyle Survey 2008**
5
6
7

8 Colette Cunningham-Myrie ¹, Emily Mabile MPH ², Ishtar Govia PhD³, Novie Younger-
9 Coleman PhD³, Marshall Tulloch-Reid DSc³, Shelly M^cFarlane PhD³, Damian Francis MSc³,
10 Georgianna Gordon-Strachan PhD³, Rainford Wilks DM³, Lisa-Gaye Greene BA⁴, Parris Lyew-
11 Ayee PhD⁴, Katherine Theall PhD⁵
12
13
14
15

16
17 ¹Department of Community Health and Psychiatry, University of the West Indies, Mona,
18 Jamaica
19

20 ²Louisiana Department of Health, Office of Public Health, Bureau of Family Health, USA
21

22 ³Caribbean Institute for Health Research, University of the West Indies, Mona, Jamaica
23

24 ⁴Mona GeoInformatics Institute, University of the West Indies, Mona, Jamaica
25

26 ⁵Department of Global Community Health and Behavioral Sciences, School of Public Health and
27 Tropical Medicine, Tulane University, USA
28
29

30
31 Corresponding author:

32 Dr. Katherine Theall
33

34 Department of Global Community Health and Behavioral Sciences
35

36 Tulane University School of Public Health and Tropical Medicine
37

38 1440 Canal Street, Suite 2300
39

40 New Orleans, LA 70112
41

42 Telephone: (504)988-4535
43

44 Email : ktheall@tulane.edu
45

46 Word count: 3939
47
48
49

50 Keywords: Cumulative Biological Risk, women, neighbourhoods, developing country
51
52
53
54
55
56
57
58
59
60

ABSTRACT

Objective To examine whether neighbourhood characteristics are associated with Cumulative Biological Risk (CBR) and sex differences in CBR in a nationally representative sample in Jamaica, a small island developing country with increasing prevalence of noncommunicable diseases (NCDs).

Design Cross-sectional study

Setting A population-based survey, the Jamaica Health and Lifestyle Survey 2008 (JHLS II) recruited persons at their homes over a four-month period from all 14 parishes and 113 neighbourhoods defined as Enumeration Districts (EDs).

Participants 2544 persons aged 15-74 years old from the 2008 Jamaica Health and Lifestyle Survey (JHLS II), who completed interviewer-administered questionnaires and had biomarkers assessed, and whose home addresses could be reliably geocoded.

Primary outcome A summary measure CBR was created using 7 markers - systolic and diastolic blood pressure readings, waist circumference, body mass index, total cholesterol, fasting blood glucose levels and self-reported asthma. Weighted multilevel models examined clustering, using the Intraclass Correlation Coefficient (ICC), of CBR across neighbourhoods and the impact of neighbourhood characteristics on CBR.

Results Women had significantly higher mean CBR scores than men across all age groups. There was significant clustering of CBR by ED, and among women versus men (ICC F= 6.9%, M= 0.7%). Women living in more disordered neighbourhoods were one-fourth as likely to have high CBR as those in less disordered ones (aOR=1.26, 95% CI=1.08-1.47; p <0.05). Recreational space availability was significantly associated with CBR: individuals living in EDs with greater recreational space availability were 25% less likely to have a high CBR (aOR=0.75, 95% CI=0.64-0.90; p <0.05).

Conclusions Policymakers in Jamaica should pay greater attention to neighbourhood factors such as recreational space availability and neighbourhood disorder that may contribute to CBR in any effort to curtail the epidemic of NCDs.

Strengths and limitations of this study

- This study provided a large sample size representative of Jamaicans 15 to 74 years.
- The study included only 7 markers to assess Cumulative Biological Risk (CBR) and had no neuroendocrine or immune biomarkers based on data unavailability.
- The neighbourhood was defined as an Enumeration District, many of which are heterogeneous, making it possible that important geographic effects may have been misclassified or not captured.
- Neighbourhood characteristics were subjectively assessed by interviewers, increasing the possibility of information bias.

INTRODUCTION

The global epidemic of the noncommunicable diseases (NCDs) has resulted in continued research efforts to understand and ameliorate the antecedents and there is accumulating evidence suggesting that cumulative biologic risk (CBR) is associated with NCDs and may be an early warning sign for later negative health outcomes [1] CBR is often operationalised as allostatic load (AL), defined as the cumulative wear and tear on physiological systems and organs due to chronic stress.[2-4] It has been posited as a key mechanism in the association between early life adversity and later health outcomes, including illness and mortality,[5] and is an important pathway that may be a link to socioeconomic and racial/ethnic health disparities.[4] The original operationalization of AL involved a count-based index from 10 markers of multisystem biological dysregulation.[6] Figure 1 represents an adaptation of a heuristic depiction of the AL model by Beckie.[7] These markers fall under two main categories: a) primary mediators, or substances the body releases in response to stress and disruption in hypothalamic-pituitary-adrenocortical (HPA) and sympathetic-adrenocortical (SAM) activity such as norepinephrine and cortisol, and b) secondary outcomes such as elevated blood pressure and body mass index (BMI), which are effects that result from the actions of the primary mediators.[8 9]

While there are numerous individual-level factors associated with elevated CBR, the neighbourhood environment may play a key direct and indirect role in shaping CBR through dysregulation of the physiologic and stress response systems and potential behavioral and health outcomes,[10-12] as well as in the production of racial and socioeconomic disparities in outcomes.[13] Neighbourhoods may impact CBR through their impact on health behaviors, e.g., neighbourhood safety has been linked to a lower likelihood of engaging in physical activity and an increased risk of obesity. [14-16] Social conditions such as high crime and neighborhood disorder, as well as poor built environments (e.g., inadequate access to healthy foods and physical and recreational activity spaces) are all too common in socioeconomically disadvantaged neighborhoods. [17]

Beyond socioeconomic status, however, few studies have examined additional neighbourhood stressors and their impact on CBR or markers of CBR. Neighborhood disorder, characterized by high levels of violence, low social control, and poor built environments,[18] may be an important factor in the production of stress and CBR, even above and beyond the impact on health behaviors. Neighbourhood disorder has been linked to markers of biologic

1
2
3 stress in both children [19] and adults.[20] Neighbourhood conditions and their association with
4 CBR, however, have not been examined in developing country contexts.

5
6 The vulnerability to social environmental stress, its impact on CBR and subsequent
7 health risk may also differ according to sex and race. Few studies exist comparing sex
8 differences in CBR, and whatever sex differences exist may vary from country to country. For
9 example, in a U.S. nationally representative study including individuals aged 17 years and older,
10 women had a higher AL than men, with larger differences after menopause.[21] However among
11 Japanese 55 to 89 years old, women had lower AL than men.[22] Another study of mostly White
12 workers aged 27 to 65 years of age in Montreal Canada, suggested that sex differences in AL
13 may be more closely related to gender roles than biological sex, per se.[23] Empirical evidence
14 for sex differences in CBR or across individual systems remains limited,[21 24-26] particularly
15 in a developing country context. Furthermore, the differential effect of neighborhood conditions
16 on CBR by sex or gender has been seldom investigated. This is despite existing evidence of a
17 differential effect of the neighborhood environment on women vs. men, due to a hypothesized
18 increased susceptibility and/or exposure of women to neighborhood effects. [27] Among adults,
19 research has shown that women subjectively experience more stress than men and consistently
20 report more physical and somatoform symptoms, and show higher stress vulnerability.[28-31]
21 [28-31]

22
23
24 With respect to race, in the US, Blacks have been shown to have higher rates of CBR or
25 AL,[4 13] live in more deprived neighbourhoods,[32] compared to Whites, and Black women
26 have shown the most consistently elevated levels of AL across age groups.[33] This provides
27 support for the “weathering hypothesis” where health decline begins in early adulthood and
28 deteriorates at an accelerated rate as a consequence of the biological manifestation of the
29 cumulative impact of repeated experience with material hardship, psychosocial challenges, and
30 social exclusion.[4]

31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Jamaica provides a unique environment for examining neighbourhood influences on
CBR and sex differences among Blacks in a developing country, given the island has a
predominantly (94%) Black population with increasing prevalence of NCDs,[34] and the
epidemiological profile mirrors that of many small island developing states, which having
undergone an epidemiological transition and are struggling to deal with the high cost of NCD
management.[35 36] The Jamaica Health and Lifestyle Surveys (JHLSs) are periodic nationally

representative surveys that allow the examination of trends overtime. Our previous secondary analysis of the JHLS II [37] revealed that differences in obesity-related outcomes may be partially explained by characteristics of the neighbourhood environment. We found there was significant interaction by sex between neighbourhood infrastructure and overweight/obesity, with a significant association in men but not women. Neighbourhood socioeconomic status,[10 13] and conditions have been positively associated with the accumulation of biological risk in developed countries.[38 39] but limited work has been done in developing countries.

Therefore, this study's purpose was to conduct secondary analysis using the JHLS II dataset, to examine the relation between neighbourhood conditions—specifically, neighborhood disorder and availability of recreational spaces—and CBR in Jamaica, as well as differences by sex in CBR rates. We hypothesize that Jamaican females will have higher CBR than their male counterparts and that CBR will be impacted by neighbourhood environments, although differentially by sex. We have chosen to use the terminology CBR instead of AL, given our survey data does not include measures of primary stress mediators.

MATERIALS AND METHODS

Study design and population

Data were obtained from the JHLS II dataset, a nationally representative cross-sectional survey conducted among 2897 individuals aged 15-74 years old between November 2007 and March 2008. The JHLS II captured health information through i) an interviewer administered survey, ii) anthropometry, and iii) bio-specimens for blood cholesterol and glucose via the finger-prick method utilizing point-of-care instruments for testing. The field team was trained in interview techniques and all were certified to conduct anthropometry and other biomedical assessments. Recruitment was conducted by random selection of clusters (enumeration districts) using a probability proportional to the size of the population within all parishes in Jamaica. Within each cluster, every 10th household was systematically selected from a randomly selected starting point, with a single individual being chosen to represent each household. Of those sampled, 353 participants did not have complete biomedical data and were excluded from the analyses, leaving a final sample of 2544 individuals analyzed. Further details on sampling methods and procedures followed to collect biomedical measures are found in the technical report.[34]

Measures

Individual-level measures

The primary outcome CBR was based on a summary score from 7 markers based on availability of data. Markers included systolic blood pressure (SBP) and diastolic blood pressure (DBP), waist circumference (WC), body mass index (BMI), total cholesterol (TC) levels and fasting blood glucose (FBG) levels. Given the absence of an inflammatory marker in the dataset, self-reported asthma was added, given that it is an inflammatory condition.[40] It has been used in previous studies assessing CBR.[38]

Each marker had a clinically defined age-specific cut-off for high risk. Adult cut-off values were: > 130 mmHg for SBP, > 85 mmHg for DBP, ≥ 94 cm for male and ≥ 80 cm for female WC,[33] ≥ 25 kg/m² for BMI, > 6.2 mM/L for TC levels [41] and ≥ 110 mg/dL (6.1mmol/L) for FBG levels.[42] CBR was examined as both a continuous and a dichotomous variable. Youth (< 18 years) were defined as being “at risk” with regard to each biomarker if their value was greater than 1 standard deviation above the mean for their age and sex or if they had a value at/above the adult cutoff value. The exception was SBP and DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for age, sex, and BMI.[43] High CBR was defined as at least one standard deviation above the mean score and a dichotomous score assigned for high or low risk (1 or 0 respectively). Scores were summed to create the total CBR score with a possible maximum score of 7.

Covariates such as age, sex, education level (< than versus \geq high school) and smoking status (currently smoke any form of tobacco) were also examined.

Household measures

The number of possessions in a household from a list of twenty items (including car ownership), was used as a proxy for reflecting socioeconomic status (SES). A complete list is documented in the technical report.[34]

Neighbourhood-level measures

The neighbourhood was defined as the enumeration district (ED) a geographical unit consisting of up to 400 dwellings. Home addresses were geographically linked to EDs within each parish using ArcGIS 10.1 (ESRI, Redlands, CA, USA). A total of 113 EDs were analysed, with an average of 15 individuals per ED. Eight percent of the sample were missing data on neighborhood-level items; however, those excluded did not differ in any way from those included in the analysis.

Interviewers' perceptions were aggregated for each subject/household and then to the ED level to obtain markers at the neighbourhood level. An index of neighbourhood disorder was created based on a composite score of the interviewers' perception of the condition of the homes, condition of the streets, condition of the yards, the amount of noise, and the air quality in the neighbourhoods. Scores for each variable ranged from 1 (excellent) to 4 (poor) and the overall index ranged from 1 to 20.

Recreational areas/playing fields/opens spaces availability was also assessed at the neighbourhood level with scores assigned 0 (no) and 1 (yes). Responses where an interviewer indicated an inability to assess or was unsure were excluded from the analysis.

Statistical analysis

Data were analyzed descriptively using SAS complex survey design methods specifying weight, stratum, and clustering variables to account for the JHLS sampling procedures when CBR was described in terms of age and sex. Means and proportions were compared using survey-weighted t-tests and the chi-squared test respectively. Two level multilevel models utilizing PROC MIXED or PROC GLIMMIX for the dichotomized CBR were employed to examine clustering of CBR across neighbourhoods and the impact of neighbourhood conditions on CBR. Multilevel models were also weighted for sampling design and survey nonresponse and regression diagnostics for linear models were conducted prior to the two-level multilevel modeling. We initially ran empty models to determine group-level influences on individual outcomes, often expressed as the Intraclass Correlation Coefficient (ICC) and calculated for our linear model as: $(V_{ED} / (V_{ED} + V_{individual})) \times 100$ where V_{ED} = variance between EDs and $V_{individual}$ = variance among individuals within EDs. An ICC at or above 2% is suggestive of a potential higher level effect (e.g., neighbourhood) and worth examining in a multilevel

1
2
3 framework.[44] Since the outcome variable is binary, the ICC was calculated using Snijders
4 formula where $V_{\text{student}} = \sqrt{2/3}$. [45 46]

5
6
7 Modeling was performed in the following steps: (1) examination of empty random
8 intercept models, in which there were no predictors, to determine the extent of clustering of CBR
9 values by neighbourhood, (2) testing the unadjusted associations between the neighbourhood
10 environments and CBR, (3) testing the adjusted association, after accounting for potential
11 confounders and testing potential interaction by sex, (4) test of random slope model, with
12 neighborhood exposures considered as random effects, and (5) final stratified models, controlling
13 for potential confounders. Models were run with and without youth, as well as with and without
14 the unconventional asthma marker to test the stability of findings.
15
16
17
18
19
20
21

22 **Ethical Approval**

23 Ethical approval was received from the Ministry of Health, Jamaica and the University Hospital
24 of the West Indies.
25
26
27
28

29 **RESULTS**

30
31 The weighted sex and age stratified statistics are shown in Table 1. The mean age was
32 approximately 35 years for each sex and 73% of women had achieved at least high school level
33 of education compared to 69% for their male counterparts. Significant sex differences were
34 noted for all the individual cardiovascular and metabolic markers with the exception of FBG,
35 with men having greater SBP and DBP and women having higher WC and TC on average.
36 Women had significantly higher mean BMI (mean = 28.50 vs. 24.50, $p < 0.05$) and significantly
37 higher mean CBR scores than men (2.38 vs. 1.68, $p < 0.01$). No clustering was observed for the
38 inflammatory marker asthma. There were no sex differences in neighbourhood exposures, with
39 similar proportions of men and women having recreation or playing areas in their community
40 and a similar mean neighbourhood disorder score (Table 1). Youth comprised approximately 4%
41 of the participants. There were also significant age differences compared to adults for all the
42 individual cardiovascular and metabolic markers, including mean FBG. For example, Table
43 1 shows that the youth had significantly lower values compared to adults for mean FBG (3.47 vs.
44 4.15, $p < 0.05$) mean BMI (23.19 vs. 27.54, $p < 0.01$) and mean CBR scores (1.06 vs. 2.26, $p <$
45 0.01).
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1. Weighted Descriptive Statistics by Sex: Jamaica Health and Lifestyle Survey 2008

Variable	Men (n=797)	Women(n=1747)	Youth (n=107)	Adults (n=2437)	Total (N= 2544)
Mean age (years)	34.89 (34.32-35.47)	35.37 (34.94-36.95)	16.09 (15.95-16.23)	36.60 (36.24-36.95)**	35.23 (15.95-36.95)
Education (%)					
< High school	31.44 (28.24-36.35)	27.16 (24.95-29.37)*	91.49 (86.38-96.61)	29.90 (27.99-31.81)**	28.43 (26.61-30.26)
≥ High school	68.55 (65.34-71.75)	72.84 (70.62-75.04)	8.51 (3.39-13.62)	70.09 (68.19-72.00)	71.56 (69.73-73.38)
Current smoker (%)	13.09 (11.96-14.23)	12.39 (10.96-13.89)	19.50 (10.78-28.17)	25.92 (24.15-27.69)*	25.48 (23.72-27.24)
Mean no. of possessions	9.69 (9.42-9.97)	9.19 (9.10-9.38)	9.26 (9.10-9.86)	9.28 (9.12-9.44)	9.34 (9.10-9.97)
Mean SBP (mmHg)	123.75 (122.72-124.79)	120.57 (119.72-121.44)*	112.82 (110.28-115.42)	122.14 (121.43-122.86)**	121.53 (119.72-124.79)
Mean DBP (mmHg)	78.33 (77.47-79.19)	76.47 (75.84-77.11)*	70.49 (68.78-72.21)	77.49 (76.95-78.02)*	77.03 (75.84-79.19)
Mean WC (cm)	82.14 (81.27-83.00)	88.69 (87.92-89.48)*	74.77 (72.96-76.58)	87.61 (86.97-88.23)**	86.74 (86.13-87.35)
Mean TC (mg/dl)	4.25 (4.21-4.28)	4.47 (4.44-4.50)*	4.14 (4.06-4.21)	4.42 (4.39-4.45)*	4.40 (4.38-4.43)
Mean FBG (mM/L)	4.12 (3.97-4.28)	4.09 (4.01-4.18)	3.47 (3.29-3.66)	4.15 (4.07-4.23)*	4.10 (4.02-4.18)
Mean BMI	24.50 (24.09-24.87)	28.50 (28.10-28.80)*	23.19 (22.23-24.13)	27.54 (27.27-28.81)**	27.25 (26.99-27.52)
Self-reported asthma (%)	5.52 (3.82-7.17)	8.23 (6.93-9.54)	8.01 (4.72-8.46)	7.24 (6.18-8.29)	7.42 (3.82-9.54)
Mean CBR score	1.68 (1.58-1.79)	2.38 (2.31-2.46)**	1.06 (0.84-1.26)	2.26 (2.19-2.32)**	2.18 (2.12-2.24)
Mean Neighbourhood Disorder score †	11.35 (11.04-11.66)	11.85 (11.62-12.08)	12.33 (11.58-13.07)	11.66 (11.47-11.85)	11.71 (11.52-11.89)
Recreational Space Availability (%) †	59.67 (55.18-64.14)	58.78 (55.35-62.20)	55.56 (44.09-66.99)	59.28 (56.50-62.06)	59.04 (56.89-61.79)

* $p < 0.05$ and ** $p < 0.01$, for comparisons between men and women and between youth and adults. Youth defined as < 18 years.

† Based on the participant's enumeration district (ED), with a total of 113 EDs in the study.

Abbreviations: SBP – Systolic Blood Pressure; DBP- Diastolic Blood Pressure; WC – Waist Circumference; TC – Total Cholesterol; FBG – Fasting Blood Glucose; BMI – Body Mass Index; CBR – Cumulative Biological Risk

1
2
3 Twenty-two percent of the sample were considered to have high CBR. Figure 2 presents
4 the total and sex-specific percentages of high CBR scores in 10-year age groups. The 35-44-
5 year-old group had the largest percentage (31%) of high CBR scores with an approximate 20%
6 difference in high scores between women and men. Sex differences in mean scores tapered off in
7 older and younger age groups but remained significant at all ages.
8
9

10
11 We observed significant clustering of CBR at the neighbourhood level with an ICC of 4.6
12 % (Figure 3). This suggests that some of the variance observed in CBR may be explained by
13 neighbourhood level factors. Significant clustering with ICC values of over 4.0 % was observed
14 for all other biomarkers except for self-reported asthma and FBG. The highest levels of
15 clustering were seen for both DBP and SBP. Also shown in Figure 3 are ICCs by sex and
16 demonstrates the substantial difference in clustering by ED between in women and men (6.9%
17 vs. 0.7%).
18
19
20
21
22
23
24
25

26 **Neighbourhood characteristics and CBR**

27 Table 2 presents combined and sex-specific results from the multilevel logistic regression
28 models utilizing CBR as a dichotomous outcome. For the combined results (adjusted for age, sex
29 and number of possessions) the likelihood of high CBR was significantly lower among
30 respondents with greater recreational space availability (aOR = 0.75; 95% CI = 0.64, 0.94;
31 $p < 0.05$). Controlling for the other individual level covariates such as smoking, diet or physical
32 activity did not alter the associations and were therefore not included in models. While the
33 overall association between neighbourhood disorder and high CBR was not statistically
34 significant, significant interaction by sex was observed. Sex-specific results revealed a
35 significant association between neighbourhood disorder score and high CBR (OR = 1.26; 95%
36 CI = 1.08, 1.47; $p < 0.05$) in women but not for men (OR = 0.97; 95% CI = 0.86, 1.09), with the
37 likelihood of high CBR increasing by 26% for each unit increase in neighbourhood disorder
38 score among women. Results were consistent when using CBR as a continuous variable.
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 2. Odds Ratio (95% CI) for High CBR[†] by Sex (N=2,544)

Neighbourhood Characteristic	Unadjusted	Adjusted ^{††}	Women	Men
Recreational Space Availability	0.79 (0.65-0.95)*	0.75 (0.64-0.90)*	0.82 (0.49-1.36)	0.91 (0.63-1.29)
ICC (%)	3.20	2.54	4.80	2.09
Neighbourhood Disorder Score	1.00 (0.97-1.03)	1.01 (0.98-1.04)	1.26 (1.08-1.47) *	0.97 (0.86-1.09)
ICC (%)	3.10	2.46	2.83	2.20

[†] High CBR was defined as at least one standard deviation above the mean score.

^{††} Adjusted for age, sex, education, no. of possessions, smoking status; stratified by sex, adjusted for age, education and no. of possessions.

* $p < 0.05$

We observed no statistically significant interaction by sex in the relationship between recreational space availability and high CBR. Inclusion of both neighbourhood exposures and individual level covariates did reduce the ICC overall. All analyses were also run with and without youth included, as well as with and without the unconventional asthma marker and there were no changes in the overall results.

DISCUSSION

This is the first study to demonstrate sex differences in CBR in a small island developing country, and the first to examine neighbourhood influences on CBR in this context. CBR increased with age for both sexes and was significantly higher among women. Higher levels of recreational space availability were associated with less CBR and greater neighbourhood disorder was significantly associated with high CBR for women but not men.

Our findings are consistent with reports elsewhere of an increase in CBR with age, at least up to the 6th decade of life.[4 21 47] In our study, CBR increased with age for both sexes, and was consistently higher among the women across the lifespan. This is consistent with studies that have found this sex differential,[22 48] but is a novel contribution to the existing literature given our study population included 15 to 74 year olds. We are unclear if this sex differential reflects genetic and/or gender underpinnings unique to the Jamaican context, or simply differences with unmeasured sample characteristics. Additionally, while our findings align with literature on poorer women's susceptibility to repeated exposures and adaptations to stressors in

1
2
3 more developed country contexts,[4] the scholarship on CBR in developing contexts such as the
4 Caribbean is limited. Studies in Jamaica have documented a strong association between morning
5 salivary cortisol levels and hypertension,[49] in mothers and their offspring. Future studies
6 examining sex differences in the association between cortisol, other specific neuroendocrine and
7 immune/inflammatory indicators used in the operationalization of CBR may explain this
8 observed sex differential. We were unable to assess racial disparities given that Jamaicans are
9 predominantly Black. However studies in the USA have found that Black women exhibit greater
10 CBR than Black men and more so than other racial groups.[4 10] This suggests possible
11 epigenetic and/or environmental underpinnings. Our analysis had no neuroendocrine markers,
12 and some are recognized to produce differentially higher response to stress in Blacks.[50]

20 The clustering of CBR across neighbourhoods indicates that some of the variance in CBR
21 may be due to neighbourhood stress or SES, and more so for women.[51] Findings corroborate
22 those that have reported the stress reducing effects of recreational spaces,[52] others that have
23 demonstrated an effect of neighborhood stress on CBR,[19 20] and add to the work examining
24 the differential impact of such contextual stress by sex. Research has shown that women
25 subjectively experience more stress than men and consistently report more physical and
26 somatoform symptoms, and show higher stress vulnerability.[28-31] Neighborhood disorder
27 may be a marker of more deprived community environments, whereby healthy food access is
28 limited [53 54] and may lead to higher CBR. For example, Kusano et al,[22] found that among
29 Japanese women those who consumed diets rich in green/yellow vegetables and meats had lower
30 AL; among men, AL was higher in alcohol users. Disorder and the stress it may induce could
31 also lead to differences in coping, particularly among women. Fernandez et al,[55] found that the
32 engagement and disengagement coping styles of African American women, measured by using
33 the Coping Strategies Inventory Short Form, were associated with CBR levels. Disorder may
34 also be related to physical activity. Our disorder marker included condition of the streets, which
35 may impact even utilitarian physical activity [56 57] and thereby CBR levels. Furthermore, our
36 marker of neighbourhood disorder included air quality, which may also directly impact CBR.[58]
37 However, our literature review has not revealed evidence supporting greater exposure of women
38 versus men to poorer air quality in residential environments. Future behavioural studies
39 exploring similar associations may help identify additional covariates which can inform sex-
40 specific interventions for reducing CBR among Jamaicans. Our finding that greater
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 neighbourhoood disorder was significantly associated with high CBR for women but not men may
4 reflect neighbourhoood disorder serving as a proxy for neighbourhoood SES.[51] While this
5 finding aligns with a few others on poorer women's susceptibility to repeated exposures and
6 adaptations to stressors in more developed country contexts,[4 13 59] similar scholarship on
7 CBR in developing contexts such as the Caribbean is limited.
8
9

10
11
12 There are potential limitations of this study. Firstly, cross-sectional data were used which
13 limits our ability to make inferences regarding causation or say definitively whether our findings
14 show age trends. The population in each age group examined is the surviving population from
15 cohorts born earlier (a selectivity bias), and may be a confounder for the pattern seen in our
16 results. It also may not be possible to generalize our results to other Black populations. Secondly,
17 we are also unclear if the observed sex differential reflects genetic, environmental and/or gender
18 underpinnings unique to the Jamaican context, or simply differences with unmeasured sample
19 characteristics. For example, our results suggest an independent effect for cumulative biological
20 risk neighborhood disorder-level context in women, but not for men. However, the analysis
21 lacked sex specific individual level data such as sex-specific exposure and physiological and/or
22 neuro-hormonal changes. Individual-level socioeconomic status effects could be more apparent
23 than aggregate neighborhood disorders or at the very least that they would provide independent
24 or confounded impacts for cumulative biological risk. Additionally, there is no agreed gold
25 standard for the operationalisation of CBR or AL. For example, our study included only 7
26 markers compared with others that used between 9 and 11 biomarkers.[7 59] In particular, as
27 stated previously we had no individual-level neuroendocrine or immune biomarkers and may
28 have missed other important associations. Of note, studies in Jamaica have documented a strong
29 association between morning salivary cortisol levels and hypertension in mothers and their
30 offspring.[49] Future studies examining sex differences in the association between cortisol,
31 other specific neuroendocrine and immune/inflammatory indicators used in the
32 operationalisation of CBR may explain this observed sex differential. Another limitation is that
33 we did not assess the use of medication for HTN, DM or TC as was done in other studies.[4 21]
34 It is possible medication use may have decreased CBR due to a shift of biomarkers below the
35 high risk cut points or increased it among the young, for whom taking medication would indicate
36 that some systemic dysregulation has already occurred.[4] Additionally, the neighbourhoood was
37 defined as an ED, many of which are heterogeneous. It is quite possible that important
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 geographic effects may have been misclassified or not captured. Neighbourhood characteristics
4 were subjectively assessed by interviewers, increasing the possibility of information bias. We
5 also had no information on the interrater reliability of neighborhood assessments, given the
6 existing nature of the data and timeframe since data collection. While we assume, given the
7 information on training of interviewer perceptions, that the reliability was high, there was no way
8 to test this. Finally, we have no data on lifetime history or risk factors (e.g. trauma or abuse,
9 childhood socioeconomic status, birthweight or childhood nutrition) that may also impact CBR
10 in adulthood.
11

12
13 Targeting neighbourhood change is feasible and may not only improve neighbourhood
14 quality but also exert a small, sustained improvement in the health of women in those
15 neighbourhoods. From a public health perspective, such structural changes offer an effective
16 alternative method for reducing health disparities. In Jamaica we have found significant clustering
17 at the neighbourhood level in obesity and significant increase in obesity among women in the
18 absence of supermarkets and markets, suggesting the need for greater emphasis on policies,
19 programmes and interventions that are focused on the neighbourhood-level effects.[60] This
20 study delves even deeper, considering potential biologic impacts that may occur irrespective of
21 women's individual behaviours, and suggests policymakers and clinicians implement
22 programmes focusing on earlier monitoring of biologic stress before NCDs develops.
23
24

25
26 The results from this study also strengthen the case for multidisciplinary local and
27 regional health research that is sensitive to sex differences in exposures and vulnerabilities that
28 likely contribute to CBR differences and related health outcomes such as NCDs. The higher
29 CBR score among women in tandem with the higher ICC levels for the women versus men by
30 EDs, suggests that gender specific factors must be considered in the development of a
31 programme of research on CBR in the Jamaican health context.[51] The sex differences in CBR
32 clustering by ED also suggests the need for multilevel models that address the possible
33 gendered vulnerabilities and exposures within the context of objective measurements of
34 neighbourhood disorder and other neighbourhood level factors.
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

STATEMENTS

Contributors CCM, IG and KT conceived the study. LG and PLA geocoded the data. CCM, EM, KT, and NYC analysed the data. CCM wrote the manuscript. MTR, SM, DF, GGS, RW and KT edited the paper. All authors approved the final manuscript.

Funding The JHLS II was supported by the National Health Fund, Jamaica.

Competing interests None declared

Ethics approval The JHLS II was approved by the Ministry of Health, Jamaica and the University Hospital of the West Indies. No additional ethical approval was necessary for this secondary data analysis.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

REFERENCES

1. Beaglehole R, Bonita R, Horton R, et al. Priority actions for the non-communicable disease crisis. *Lancet* 2011;377(9775):1438-47
2. McEwen BS, Stellar E. Stress and the individual: mechanisms leading to disease. *Arch Intern Med* 1993;153(18):2093
3. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998;338(3):171
4. Geronimus AT, Hicken M, Keene D, et al. "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *Am J Public Health* 2006;96(5):826-33 doi: 10.2105/ajph.2004.060749[published Online First: Epub Date]
5. Borrell LN, Dallo FJ, Nguyen N. Racial/ethnic disparities in all-cause mortality in US adults: the effect of allostatic load. *Public Health Rep* 2010;125(6):810
6. Seeman TE, Singer BH, Rowe JW, et al. Price of adaptation--allostatic load and its health consequences. MacArthur studies of successful aging. *Arch Intern Med* 1997;157(19):2259-68
7. Beckie TM. A Systematic Review of Allostatic Load, Health, and Health Disparities. *Biol Res Nurs* 2012;14(4):311-46
8. McEwen B, Seeman T. Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. *Ann N Y Acad Sci* 1999;896(1):30-47
9. Seeman TE, McEwen BS. Social environment characteristics and neuroendocrine function: the impact of social ties and support on neuroendocrine regulation. *Psychosom Med* 1996;58(5):459-71
10. Bird CE, Seeman T, Escarce JJ, et al. Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *J Epidemiol Community Health* 2010;64(10):860-5 doi: 10.1136/jech.2008.084814[published Online First: Epub Date].
11. King KE, Morenoff JD, House JS. Neighborhood context and social disparities in cumulative biological risk factors. *Psychosom Med* 2011;73(7):572-79

12. Schulz AJ, Mentz G, Lachance L, et al. Associations between socioeconomic status and allostatic load: effects of neighborhood poverty and tests of mediating pathways. *Am J Public Health* 2012;102(9):1706-14
13. Merkin S, Basurto-Dávila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of US adults: NHANES III. *Ann Epidemiol* 2009;19(3):194
14. Robinson AI, Carnes F, Oreskovic NM. Spatial analysis of crime incidence and adolescent physical activity. *Prev Med* 2016;85:74-7 doi: 10.1016/j.ypmed.2016.01.012[published Online First: Epub Date].
15. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;36(6):484-90 doi: 10.1016/j.amepre.2009.01.031[published Online First: Epub Date].
16. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999;29(6 Pt 1):563-70 doi: 10.1006/pmed.1999.0585[published Online First: Epub Date].
17. Gordon-Larsen P, Nelson MC, Page P, et al. Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics* 2006;117(2):417-24 doi: 10.1542/peds.2005-0058[published Online First: Epub Date].
18. Ross C, Mirowsky J. Neighborhood disadvantage, disorder, and health. *J. Health Soc Behav* 2001;43(2):258-76.
19. Theall KP, Brett ZH, Shirtcliff EA, et al. Neighborhood disorder and telomeres: connecting children's exposure to community level stress and cellular response. *Soc Sci Med* 2013;85:50-8 doi: 10.1016/j.socscimed.2013.02.030[published Online First: Epub Date].
20. Hosseini F, Adha N, Zainol R, et al. Neighborhood-Level Stress and Circadian Cortisol: A Systematic Review and Meta-Analysis. *Iran J Public Health* 2014;43(10):1324-34
21. Yang Y, Kozloski M. Sex differences in age trajectories of physiological dysregulation: inflammation, metabolic syndrome, and allostatic load. *J Gerontol A Biol Sci Med Sci* 2011;66(5):493-500 doi: 10.1093/gerona/glr003[published Online First: Epub Date].

- 1
2
3 22. Kusano Y, Crews DE, Iwamoto A, et al. Allostatic load differs by sex and diet, but not age in
4 older Japanese from the Goto Islands. *Ann Human Biol* 2015;1-8 doi:
5 10.3109/03014460.2015.1013985[published Online First: Epub Date].
6
7
8 23. Juster R-P, Lupien S. A sex-and gender-based analysis of allostatic load and physical
9 complaints. *Gend Med* 2012;9(6):511-23
10
11 24. Lloyd-Jones DM, Wilson PWF, Larson MG, et al. Framingham risk score and prediction of
12 lifetime risk for coronary heart disease. *Am J Cardiol* 2004;94(1):20-24 doi:
13 10.1016/j.amjcard.2004.03.023[published Online First: Epub Date].
14
15 25. Eskes T, Haanen C. Why do women live longer than men? *Eur J Obstet Gynecol Reprod Biol*
16 2007;133(2):126-33 doi: 10.1016/j.ejogrb.2007.01.006[published Online First: Epub Date].
17
18 26. Schuurs AHWM, Verheul HAM. Effects of gender and sex steroids on the immune response.
19 *J Steroid Biochem* 1990;35(2):157-72 doi: 10.1016/0022-4731(90)90270-3[published Online
20 First: Epub Date].
21
22 27. Stafford M, Cummins S, Macintyre S, et al. Gender differences in the associations between
23 health and neighbourhood environment. *Soc Sci Med* 2005;60(8):1681-92 doi:
24 10.1016/j.socscimed.2004.08.028[published Online First: Epub Date].
25
26 28. Barnett R, Biener L, Baruch G. Gender and stress: The Free Press, 1987.
27
28 29. Bebbington P, Dunn G, Jenkins R, et al. The influence of age and sex on the prevalence of
29 depressive conditions: report from the National Survey of Psychiatric Morbidity. *Int*
30 *Rev Psychiatry* 2003;15(1-2):74-83
31
32 30. Kessler R, Brown R, Broman C. Sex differences in psychiatric help-seeking: Evidence from
33 four large-scale surveys. *J Health Soc. Behav* 1981:49-64
34
35 31. Kessler R, McLeod J. Sex differences in vulnerability to undesirable life events. *Am Sociol*
36 *Rev* 1984:620-31
37
38 32. LaVeist TA, Wallace JM, Jr. Health risk and inequitable distribution of liquor stores in
39 African American neighborhood. *Soc Sci Med* 2000;51(4):613-7
40
41 33. Lean M, Han T, Morrison C. Waist circumference as a measure for indicating need for
42 weight management. *BMJ* 1995;311(6998):158
43
44 34. Wilks R, Younger N, Tulloch-Reid M, et al. Jamaica Health and Lifestyle Survey 2007-8. .
45 Secondary Jamaica Health and Lifestyle Survey 2007-8. 2008.
46
47 http://www.mona.uwi.edu/reports/health/JHLSII_final_may09.pdf.
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3 35. Abdulkadri AO, Cunningham-Myrie C, Forrester T. Economic burden of diabetes and
4 hypertension in CARICOM states. *Soc Econ Stud* 2009;58 (3 &4):175-97
5
6 36. Hospedales CJ, Samuels T, Cummings R, et al. Raising the priority of chronic
7 noncommunicable diseases in the Caribbean. *Rev Panam Salud Pública* 2011;30(4):393-400
8
9 37. Cunningham-Myrie CA, Theall KP, Younger NO, et al. Associations between neighborhood
10 effects and physical activity, obesity, and diabetes: The Jamaica Health and Lifestyle Survey
11 2008. *J Clin Epidemiol* 2015;68(9):970-8. doi: 10.1016/j.jclinepi.2014.08.004. Epub 2015 Apr
12 22.
13
14 38. Theall KP, Drury SS, Shirtcliff EA. Cumulative Neighborhood Risk of Psychosocial Stress
15 and Allostatic Load in Adolescents. *Am J Epidemiol* 2011;176(suppl 7):S164-S74 doi:
16 10.1093/aje/kws185[published Online First: Epub Date].
17
18 39. Chum A, O'Campo P. Cross-sectional associations between residential environmental
19 exposures and cardiovascular diseases. *BMC Public Health* 2015;15(1):438
20
21 40. Barnes PJ. Immunology of asthma and chronic obstructive pulmonary disease. *Nat Rev*
22 *Immunol* 2008;8(3):183-92 doi: 10.1038/nri2254[published Online First: Epub Date].
23
24 41. Roth GA, Fihn SD, Mokdad AH, et al. High total serum cholesterol, medication coverage
25 and therapeutic control: an analysis of national health examination survey data from eight
26 countries. *Bull World Health Organ* 2011;89(2):92-101
27
28 42. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate
29 hyperglycaemia: report of a WHO/IDF Consultation Report. 2006
30
31 43. Koebnick C, Black MH, Wu J, et al. High blood pressure in overweight and obese youth:
32 implications for screening. *J Clin Hypertens (Greenwich)* 2013;15(11):793-805 doi:
33 10.1111/jch.12199[published Online First: Epub Date].
34
35 44. Raudenbush SW, Bryk AS. Hierarchical linear models: Applications and data analysis
36 methods: Sage Publications, Incorporated, 2001.
37
38 45. Snijders TAB, Bosker RJ. Multilevel analysis: an introduction to basic and advanced
39 multilevel modeling. Thousand Oaks, Calif. ; London: SAGE, 1999.
40
41 46. Merlo J, Chaix B, Ohlsson H, et al. A brief conceptual tutorial of multilevel analysis in social
42 epidemiology: using measures of clustering in multilevel logistic regression to investigate
43 contextual phenomena. *J Epidemiol Community Health* 2006;60(4):290-7 doi:
44 10.1136/jech.2004.029454[published Online First: Epub Date].
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3 47. Crimmins EM, Johnston M, Hayward M, et al. Age differences in allostatic load: an index of
4 physiological dysregulation. *Exp Gerontol* 2003;38(7):731-34
5
6 48. Mair CA, Cutchin MP, Peek MK. Allostatic load in an environmental riskscape: The role of
7 stressors and gender. *Health Place* 2011;17(4):978-87
8
9 49. Boyne MS, Woollard A, Phillips DI, et al. The association of hypothalamic-pituitary-adrenal
10 axis activity and blood pressure in an Afro-Caribbean population. *Psychoneuroendocrinology*
11 2009;34(5):736-42 doi: 10.1016/j.psyneuen.2008.12.005[published Online First: Epub Date].
12
13 50. Chong RY, Uhart M, McCaul ME, et al. Whites have a more robust hypothalamic-pituitary-
14 adrenal axis response to a psychological stressor than blacks. *Psychoneuroendocrinology*
15 2008;33(2):246-54 doi: 10.1016/j.psyneuen.2007.10.014[published Online First: Epub Date].
16
17 51. Mullings JA, McCaw-Binns AM, Archer C, et al. Gender differences in the effects of urban
18 neighborhood on depressive symptoms in Jamaica. *Rev Panam Salud Pública* 2013;34(6):385-92
19
20 52. Stigsdotter UK, Ekholm O, Schipperijn J, et al. Health promoting outdoor environments--
21 associations between green space, and health, health-related quality of life and stress based on a
22 Danish national representative survey. *Scand J Public Health* 2010;38(4):411-7 doi:
23 10.1177/1403494810367468[published Online First: Epub Date].
24
25 53. Bower KM, Thorpe RJ, Jr., Rohde C, et al. The intersection of neighborhood racial
26 segregation, poverty, and urbanicity and its impact on food store availability in the United States.
27 *Prev Med* 2014;58:33-9 doi: 10.1016/j.ypmed.2013.10.010[published Online First: Epub Date].
28
29 54. Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the location
30 and type of food stores. *Am J Public Health* 2006;96(2):325-31
31
32 55. Fernandez CA, Loucks EB, Arheart KL, et al. Evaluating the Effects of Coping Style on
33 Allostatic Load, by Sex: The Jackson Heart Study, 2000-2004. *Prev Chronic Dis* 2015;12:E165
34 doi: 10.5888/pcd12.150166[published Online First: Epub Date].
35
36 56. Lee C, Ory MG, Yoon J, et al. Neighborhood walking among overweight and obese adults:
37 age variations in barriers and motivators. *J Community Health* 2013;38(1):12-22 doi:
38 10.1007/s10900-012-9592-6[published Online First: Epub Date].
39
40 57. Miles R, Panton LB, Jang M, et al. Residential context, walking and obesity: two African-
41 American neighborhoods compared. *Health Place* 2008;14(2):275-86 doi:
42 10.1016/j.healthplace.2007.07.002[published Online First: Epub Date].
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
2
3 58. Clougherty JE, Kubzansky LD. A framework for examining social stress and susceptibility to
4 air pollution in respiratory health. *Environ Health Perspect* 2009;117(9):1351-8 doi:
5 10.1289/ehp.0900612[published Online First: Epub Date].
6
7
8 59. Hickson DA, Diez Roux AV, Gebreab SY, et al. Social Patterning of Cumulative Biological
9 Risk by Education and Income Among African Americans. *Am J Public Health*
10 2012;102(7):1362-69 doi: 10.2105/ajph.2011.300444[published Online First: Epub Date].
11
12 60. Myrie CA. An Exploration of Geographic Variation in Obesity, Its Key Risk Factors and
13 Comorbidities. Are There Opportunities for Tailoring Public Health Interventions? Secondary
14 Analysis of The Jamaica Health and Lifestyle Survey 2008 (JHLS II), 2017.
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8 **Figure 1** Heuristic model: Allostatic load, health and health disparities

9
10 Adapted from Beckie TM. A Systematic Review of Allostatic Load, Health, and Health
11 Disparities.[7]
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1
2
3
4
5
6
7 **Figure 2** Proportion High CBR[†] score by age and sex

8 CBR – Cumulative Biological Risk

9 [†]High CBR was defined as at least one standard deviation above the mean score.

10 *p < 0.01, **p < 0.0001
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7 **Figure 3** Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High
8 Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.
9

10 CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure;
11 WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body
12 Mass Index* High CBR was defined as at least one standard deviation above the mean score.

13 ** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma,
14 DBP > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and
15 BMI \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation
16 above the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and
17 DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for
18 age, sex, and BMI.
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

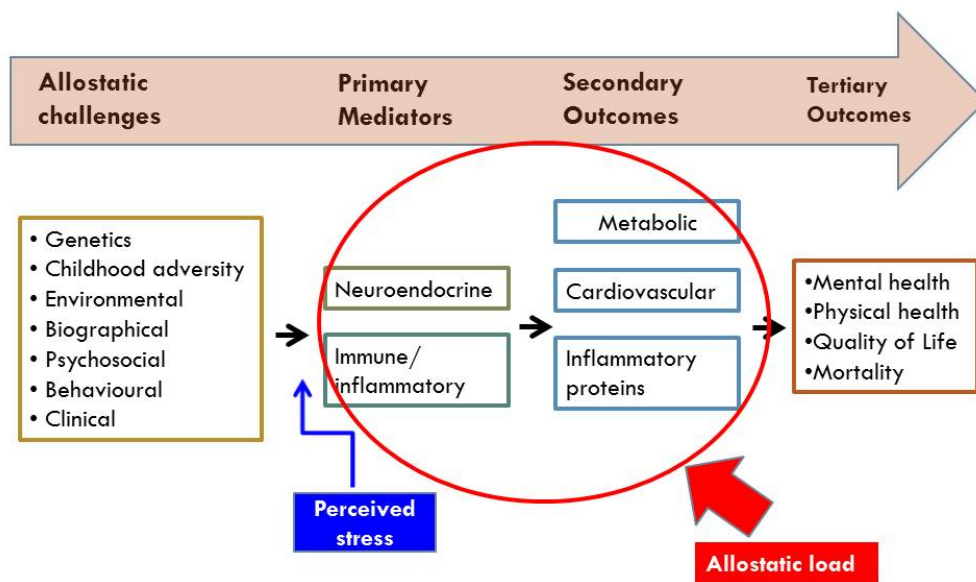


Figure 1 Heuristic model: Allostatic load, health and health disparities Adapted from Beckie TM. A Systematic Review of Allostatic Load, Health, and Health Disparities.[7]

254x190mm (96 x 96 DPI)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

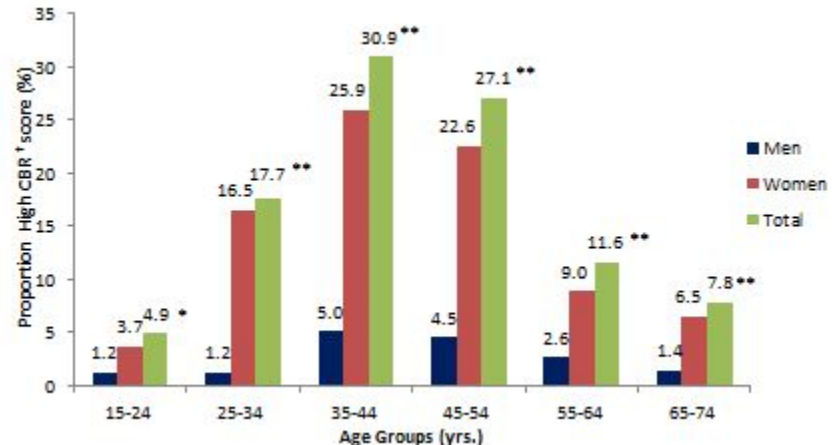


Figure 2 Proportion High CBR+ score by age and sex CBR – Cumulative Biological Risk †High CBR was defined as at least one standard deviation above the mean score. *p < 0.01, **p < 0.0001

111x61mm (96 x 96 DPI)

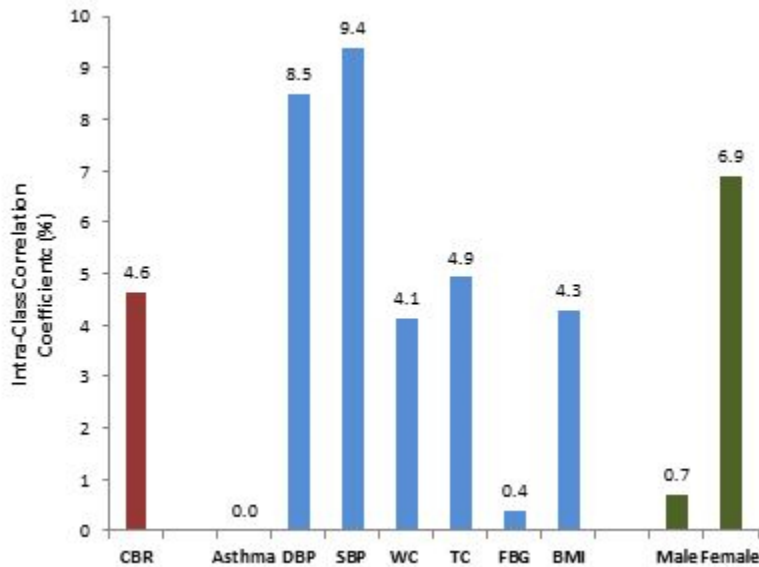


Figure 3 Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex. CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure; WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body Mass Index* High CBR was defined as at least one standard deviation above the mean score.** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma, DBP > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and BMI \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for age, sex, and BMI.

105x78mm (96 x 96 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-9
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	8-9
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	8
		(e) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6-8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Neighbourhood Characteristics and Cumulative Biological Risk in a Developing Country: Evidence from the Jamaica Health and Lifestyle Survey 2008

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-021952.R1
Article Type:	Research
Date Submitted by the Author:	21-Jun-2018
Complete List of Authors:	Cunningham-Myrie, Colette; University of the West Indies at Mona Faculty of Medical Sciences, Community Health and Psychiatry Mabile, Emily; Louisiana Office of Public Health, Bureau of Family Health Govia, Ishtar; University of the West Indies, Caribbean Institute for Health Research Younger, Novie; University of the West Indies, Caribbean Institute for Health Research Tulloch-Reid, Marshall; The University of the West Indies , Caribbean Institute for Health Research McFarlane, Shelly ; University of the West Indies, Caribbean Institute for Health Research Francis, Damian; University of the West Indies, Caribbean Institute for Health Research Gordon-Strachan, Georgiana; University of the West Indies, Caribbean Institute for Health Research Wilks, Rainford; University of the West Indies, Caribbean Institute for Health Research Greene, Lisa-Gaye; University of the West Indies, Mona GeoInformatics Institute Lyew-Ayee, Parris; University of the West Indies, Mona GeoInformatics Institute Theall, Katherine; Tulane University, Global Community Health and Behavioral Sciences
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	developing country, cumulative biological risk, women, neighbourhoods

SCHOLARONE™
Manuscripts

1
2
3 **Neighbourhood Characteristics and Cumulative Biological Risk in a Developing**
4 **Country: Evidence from the Jamaica Health and Lifestyle Survey 2008**
5
6

7 Colette Cunningham-Myrie ¹, Emily Mabile MPH ², Ishtar Govia PhD³, Novie Younger-
8 Coleman PhD³, Marshall Tulloch-Reid DSc³, Shelly M^cFarlane PhD³, Damian Francis MSc³,
9 Georgianna Gordon-Strachan PhD³, Rainford Wilks DM³, Lisa-Gaye Greene BA⁴, Parris
10 Lyew-Ayee PhD⁴, Katherine Theall PhD⁵
11
12
13
14

15 ¹Department of Community Health and Psychiatry, University of the West Indies, Mona,
16 Jamaica
17

18 ²Louisiana Department of Health, Office of Public Health, Bureau of Family Health, USA
19

20 ³Caribbean Institute for Health Research, University of the West Indies, Mona, Jamaica
21

22 ⁴Mona GeoInformatics Institute, University of the West Indies, Mona, Jamaica
23

24 ⁵Department of Global Community Health and Behavioral Sciences, School of Public Health
25 and Tropical Medicine, Tulane University, USA
26
27

28
29 Corresponding author:

30 Dr. Katherine Theall

31 Department of Global Community Health and Behavioral Sciences

32 Tulane University School of Public Health and Tropical Medicine

33 1440 Canal Street, Suite 2300

34 New Orleans, LA 70112

35 Telephone: (504)988-4535

36 Email : ktheall@tulane.edu
37
38
39
40
41
42

43 Word count: 4405
44
45

46 Keywords: Cumulative Biological Risk, women, neighbourhoods, developing country
47
48
49
50
51
52
53
54
55
56
57
58
59
60

ABSTRACT

Objective To examine whether neighbourhood characteristics are associated with Cumulative Biological Risk (CBR) and sex differences in CBR in a nationally representative sample in Jamaica, a small island developing country with increasing prevalence of noncommunicable diseases (NCDs).

Design Cross-sectional study

Setting A population-based survey, the Jamaica Health and Lifestyle Survey 2008 (JHLS II) recruited persons at their homes over a four-month period from all 14 parishes and 113 neighbourhoods defined as Enumeration Districts (EDs).

Participants 2544 persons aged 15-74 years old from the 2008 Jamaica Health and Lifestyle Survey (JHLS II), who completed interviewer-administered questionnaires and had biomarkers assessed, and whose home addresses could be reliably geocoded.

Primary outcome A summary measure CBR was created using 7 markers - systolic and diastolic blood pressure readings, waist circumference, body mass index, total cholesterol, fasting blood glucose levels and self-reported asthma. Weighted multilevel models examined clustering, using the Intraclass Correlation Coefficient (ICC), of CBR across neighbourhoods and the impact of neighbourhood characteristics (recreational space availability and neighbourhood disorder) on CBR.

Results Women had significantly higher mean CBR scores than men across all age groups. There was significant clustering of CBR by ED, and among women versus men (ICC F= 6.9%, M= 0.7%). Women living in more disordered neighbourhoods were 26% more likely to have high CBR as those in less disordered ones (aOR=1.26, 95% CI=1.08-1.47; p <0.05). Individuals living in EDs with greater recreational space availability were 25% less likely to have a high CBR (aOR=0.75, 95% CI=0.64-0.90; p <0.05).

Conclusions Policymakers in Jamaica should pay greater attention to neighbourhood factors such as recreational space availability and neighbourhood disorder that may contribute to CBR in any effort to curtail the epidemic of NCDs.

Strengths and limitations of this study

- This study provided a large sample size representative of Jamaicans 15 to 74 years.
- The study examines the role of neighbourhood context, including factors beyond socioeconomic status, on biologic stress in a middle income country context.
- The study included only 7 markers to assess Cumulative Biological Risk (CBR) and had no neuroendocrine or immune biomarkers based on data unavailability.
- The neighbourhood was defined as an Enumeration District, many of which are heterogeneous, making it possible that important geographic effects may have been misclassified or not captured.
- Neighbourhood characteristics were subjectively assessed by interviewers, increasing the possibility of information bias.

INTRODUCTION

The global epidemic of the noncommunicable diseases (NCDs) has resulted in continued research efforts to understand and ameliorate the antecedents, and there is accumulating evidence suggesting that cumulative biologic risk (CBR) is associated with NCDs and may be an early warning sign for later negative health outcomes. [1] CBR is often operationalised as allostatic load (AL), defined as the cumulative wear and tear on physiological systems and organs due to chronic stress.[2-4] It has been posited as a key mechanism in the association between early life adversity and later health outcomes, including illness and mortality,[5] and is an important pathway that may be a link to socioeconomic and racial/ethnic health disparities.[4] The original operationalization of AL involved a count-based index from 10 markers of multisystem biological dysregulation[6] [7]that fall under two main categories: a) primary mediators, or substances the body releases in response to stress and disruption in hypothalamic-pituitary-adrenocortical (HPA) and sympathetic-adrenocortical (SAM) activity such as norepinephrine and cortisol, and b) secondary outcomes such as elevated blood pressure and body mass index (BMI), which are effects that result from the actions of the primary mediators.[8, 9] From a population health perspective, it is important to identify potential factors amenable to change that may impact CBR on a larger scale.

The neighbourhood environment may play a key direct and indirect role in shaping CBR through dysregulation of the physiologic and stress response systems and potential behavioral and health outcomes,[10-12] as well as in the production of racial and socioeconomic disparities in outcomes.[13] Neighbourhoods may impact CBR through their impact on health behaviors, e.g., neighbourhood safety has been linked to a lower likelihood of engaging in physical activity and an increased risk of obesity. [14-16] Social conditions such as high crime and neighbourhood disorder, as well as poor built environments (e.g., inadequate access to healthy foods and physical and recreational activity spaces) are all too common in socioeconomically disadvantaged neighbourhoods. [17]

Beyond socioeconomic status, however, few studies have examined additional neighbourhood stressors and their impact on CBR or markers of CBR. Neighbourhood disorder, characterized by high levels of violence, low social control, and poor built environments,[18] may be an important factor in the production of stress and CBR, even above and beyond the impact on health behaviors. Neighbourhood disorder has been linked to markers of biologic stress in both children [19] and adults.[20] It is also important to examine specific aspects of disordered neighbourhoods, such as built environments like physical activity or recreational space availability. Availability of spaces to be physically

1
2
3 active has been linked to NCDs like obesity[21, 22] and NCD risk factors.[23]
4 Neighbourhood conditions and their association with CBR, however, have not been examined
5 in developing country contexts.
6

7
8 The vulnerability to social environmental stress, its impact on CBR and subsequent
9 health risk may also differ according to sex and race. Few studies exist comparing sex
10 differences in CBR, and whatever sex differences exist may vary from country to country.
11 For example, in a U.S. nationally representative study including individuals aged 17 years
12 and older, women had a higher AL than men, with larger differences after menopause.[24]
13 However among Japanese 55 to 89 years old, women had lower AL than men.[25] Another
14 study of mostly White workers aged 27 to 65 years of age in Montreal Canada, suggested that
15 sex differences in AL may be more closely related to gender roles than biological sex, per
16 se.[26] Empirical evidence for sex differences in CBR or across individual systems remains
17 limited,[24, 27-29] particularly in a developing country context. Furthermore, the differential
18 effect of neighbourhood conditions on CBR by sex or gender has been seldom investigated.
19 This is despite existing evidence of a differential effect of the neighbourhood environment on
20 women vs. men, due to a hypothesized increased susceptibility and/or exposure of women to
21 neighbourhood effects. [30] Among adults, research has shown that women subjectively
22 experience more stress than men and consistently report more physical and somatoform
23 symptoms, and show higher stress vulnerability.[31-34] [31-34] With respect to race, in the
24 US, Blacks have been shown to have higher rates of CBR or AL,[4, 13] live in more deprived
25 neighbourhoods,[35] compared to Whites, and Black women have shown the most
26 consistently elevated levels of AL across age groups.[36]
27

28
29 Neighbourhood socioeconomic status,[10, 13] and conditions have been positively
30 associated with the accumulation of biological risk in developed countries.[37, 38] but
31 limited work has been done in developing countries. Jamaica provides a unique environment
32 for examining neighbourhood influences on CBR and differences between Black women and
33 men in a developing country, given the island has a predominantly (94%) Black population
34 with increasing prevalence of NCDs.[39] The epidemiological profile of NCDs in Jamaica
35 mirrors that of many small island developing states having undergone an epidemiological
36 transition and are struggling to deal with the high cost of NCD management.[40, 41]
37 Furthermore, increasing levels of poverty in the country, [42] coupled with high levels of
38 neighbourhood-level social stratification and potential consequences of stratification (e.g.,
39 crime, discrimination) in Jamaica[43] may be contributing significantly to rates of NCD and
40 risk factors like CBR. However, few studies have examined more distal exposures, with the
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 exception of a handful focused on mental health outcomes [44, 45] and our previous
4 secondary analysis of the National Jamaica Health and Lifestyle Surveys (JHLS) II [46],
5 which revealed that differences in obesity-related outcomes may be partially explained by
6 characteristics of the neighbourhood environment. We found an impact of neighbourhood
7 infrastructure on overweight/obesity that differed by sex, with a significant association in
8 men but not women.
9

10
11
12 Within the contemporary Jamaican and US contexts, there are key indicators of social
13 stratification that set men and women apart (e.g., single parenthood, household headship, and
14 poverty) and that are related to differences in the prevalence and incidence of physical and
15 mental health outcomes. Examination of differences within otherwise homogenous
16 geographic or social communities provides a more organic understanding of the theories of
17 fundamental cause in terms of “spatial externalities” (e.g., economic policies made at the
18 community level) which may allow for better design of effective population level
19 interventions.[47, 48] In the proposed study, we aim to examine the production of biologic
20 stress in a seemingly homogenous racial population and how such structural factors may be
21 embodied,[49] providing a comprehensive socioecological framework that will inform
22 treatment and prevention efforts in middle income countries like Jamaica as well as those
23 aimed at reducing disparities in the US by targeting differences within groups.[46][37, 38]
24
25

26
27 Through a secondary analysis of the JHLS II dataset, we examine the relation between
28 neighbourhood conditions—specifically, neighbourhood disorder and availability of
29 recreational spaces—and CBR in Jamaica, as well as differences by sex. We hypothesized
30 that Jamaican females will have higher CBR than their male counterparts and that CBR will
31 be impacted by neighbourhood environments, although differentially by sex. We have
32 chosen to use the terminology CBR instead of AL, given our survey data does not include
33 measures of primary stress mediators.
34
35
36
37
38
39
40
41
42
43
44
45

46 **MATERIALS AND METHODS**

47 **Study design and population**

48
49 Data were obtained from the JHLS II dataset, a nationally representative cross-sectional
50 survey conducted among 2897 individuals aged 15-74 years old between November 2007 and
51 March 2008. The JHLS II captured health information through i) an interviewer administered
52 survey, ii) anthropometry, and iii) bio-specimens for blood cholesterol and glucose via the
53 finger-prick method utilizing point-of-care instruments for testing. The field team was trained
54
55
56
57
58
59

1
2
3 in interview techniques and all were certified to conduct anthropometry and other biomedical
4 assessments. Recruitment was conducted by random selection of clusters (enumeration
5 districts) using a probability proportional to the size of the population within all parishes in
6 Jamaica. Within each cluster, every 10th household was systematically selected from a
7 randomly selected starting point, with a single individual being chosen to represent each
8 household. Of those sampled, 353 participants did not have complete biomedical data and
9 were excluded from the analyses, leaving a final sample of 2544 individuals analyzed.
10 Further details on sampling methods and procedures followed to collect biomedical measures
11 are found in the technical report.[39]
12
13
14
15
16
17
18

19 **Patient and public involvement**

20 Study participants were generally residents of communities and no patients were involved in
21 the study. The study participants were not involved in the design, recruitment or the conduct
22 of the study. The study findings will be disseminated to the Ministry of Health, Jamaica and
23 general public, including the study participants.
24
25
26
27
28

29 **Measures**

30 *Individual-level measures*

31 The primary outcome CBR was based on a summary score from 7 markers based on
32 availability of data. Markers included systolic blood pressure (SBP) and diastolic blood
33 pressure (DBP), waist circumference (WC), body mass index (BMI), total cholesterol (TC)
34 levels and fasting blood glucose (FBG) levels. Given the absence of an inflammatory marker
35 in the dataset, self-reported asthma was added, given that it is an inflammatory condition.[50]
36 It has been used in previous studies assessing CBR.[37]
37
38
39
40
41

42 Each marker had a clinically defined age-specific cut-off for high risk. Adult cut-off
43 values were: > 130 mmHg for SBP, > 85 mmHg for DBP, ≥ 94 cm for male and ≥ 80 cm for
44 female WC,[36] ≥ 25 kg/m² for BMI, > 6.2 mM/L for TC levels [51] and ≥ 110 mg/dL
45 (6.1mmol/L) for FBG levels.[52] CBR was examined as both a continuous and a
46 dichotomous variable. High CBR was defined as at least one standard deviation above the
47 mean score and a dichotomous score assigned for high or low risk (1 or 0 respectively).
48 Scores were summed to create the total CBR score with a possible maximum score of 7 (
49 self-reported asthma included). Youth (< 18 years) were defined as being “at risk” with
50 regard to each biomarker if their value was greater than 1 standard deviation above the mean
51 for their age and sex or if they had a value at/above the adult cutoff value. The exception was
52
53
54
55
56
57
58
59
60

1
2
3 SBP and DBP, with high risk cut-points defined as being greater than or equal to the 94th
4 percentile for age, sex, and BMI.[53]
5

6 Covariates such as age, sex, education level (< than versus ≥ high school) and
7 smoking status (currently smoke any form of tobacco) were also examined. Further details on
8 how these variables were assessed can be found in the technical report.[39]
9
10

11 *Household measures*

12 The number of possessions in a household from a list of twenty items (including car
13 ownership), was used as a proxy for reflecting socioeconomic status (SES). Household
14 crowding was also examined as a potential confounder, defined as both more than one person
15 per habitable room as well as the average number of individuals per habitable room. A
16 complete list is documented in the technical report.[39]
17
18
19
20
21

22 *Neighbourhood-level measures*

23 The neighbourhood was defined as the enumeration district (ED) a geographical unit
24 consisting of up to 400 dwellings. Home addresses were geographically linked to EDs within
25 each parish using ArcGIS 10.1 (ESRI, Redlands, CA, USA). A total of 113 EDs were
26 analysed, with an average of 15 individuals per ED.
27
28
29
30
31

32 Interviewers' perceptions were aggregated for each subject/household and then to the
33 ED level to obtain markers at the neighbourhood level. An index of neighbourhood disorder
34 was created based on a composite score of the interviewers' perception of the condition of the
35 homes, condition of the streets, condition of the yards, the amount of noise, and the air
36 quality in the neighbourhoods. Scores for each variable ranged from 1 (excellent) to 4 (poor)
37 and the overall index ranged from 1 to 20, and therefore higher total scores indicated greater
38 neighbourhood disorder. While there are no gold standard measures for neighbourhood
39 disorder, indices representing both social and physical disorder in communities have been
40 widely employed and utilizing both self-reported or perceived as well as objective
41 measures.[19, 54-56] Some have included only markers of physical disorder, as is the case in
42 the present study and a limitation; however, physical disorder has been closely linked to
43 social disorder but may not necessarily be a marker of social disorder.[57-59] Nonetheless,
44 physical disorder may contribute to biologic stress markers such as CBR, irrespective of
45 social disorder.
46
47
48
49
50
51
52
53

54 Recreational areas/playing fields/opens spaces availability in the participant's
55 neighbourhood was also assessed based on the interviewer's perception of a) the presence of
56
57
58
59
60

1
2
3 and b) walking distance to either recreational spaces, playing fields or other open spaces from
4 a participant's home. Scores assigned were 0 (no) and 1 (yes), with a total possible
5 maximum score of 2. Responses where an interviewer indicated an inability to assess or was
6 unsure were excluded from the analysis at the individual level. Eight percent of respondents
7 were missing data on neighbourhood-level items; however, those excluded did not differ in
8 any way from those included in the analysis. Both disorder and recreational availability were
9 individual-level measures, assessed based on the participant's home and immediate walking
10 area around the home; therefore, missing data was only at the level of the individual and not
11 the ED.
12
13
14
15
16
17
18

19 **Statistical analysis**

20 Data were analyzed descriptively using SAS complex survey design methods specifying
21 weight, stratum, and clustering variables to account for the JHLS sampling procedures when
22 CBR was described in terms of age and sex. Means and proportions were compared using
23 survey-weighted t-tests and the chi-squared test respectively. Two level multilevel models
24 utilizing PROC MIXED or PROC GLIMMIX for the dichotomized CBR were employed to
25 examine clustering of CBR across neighbourhoods and the impact of neighbourhood
26 conditions on CBR. Multilevel models were also weighted for sampling design and survey
27 nonresponse and regression diagnostics for linear models were conducted prior to the two-
28 level multilevel modeling. We initially ran empty models to determine group-level influences
29 on individual outcomes, often expressed as the Intraclass Correlation Coefficient (ICC) and
30 calculated for our linear model as: $(V_{ED} / (V_{ED} + V_{individual})) \times 100$ where V_{ED} = variance
31 between EDs and $V_{individual}$ = variance among individuals within EDs. An ICC at or above 2%
32 is suggestive of a potential higher level effect (e.g., neighbourhood) and worth examining in a
33 multilevel framework.[60] Since the outcome variable is binary, the ICC was calculated
34 using Snijders formula where $V_{student} = \frac{1}{3}$. [61, 62]
35
36
37
38
39
40
41
42
43
44

45 Modeling was performed in the following steps: (1) examination of empty random
46 intercept models, in which there were no predictors, to determine the extent of clustering of
47 CBR values by neighbourhood, (2) testing the unadjusted associations between the
48 neighbourhood environments and CBR, (3) testing the adjusted association, after accounting
49 for potential confounders and testing potential interaction by sex, (4) test of random slope
50 model, with neighborhood exposures considered as random effects, and (5) final stratified
51
52
53
54
55
56
57
58
59
60

1
2
3 models, controlling for potential confounders. Models were run with and without youth, as
4 well as with and without the unconventional asthma marker to test the stability of findings.
5
6

7 **Ethical Approval**

8 Ethical approval was received from the Ministry of Health, Jamaica and the University
9 Hospital of the West Indies.
10
11
12

13 **RESULTS**

14 The weighted sex and age stratified statistics are shown in Table 1. The mean age was
15 approximately 35 years for each sex and 73% of women had achieved at least high school
16 level of education compared to 69% for their male counterparts. Significant sex differences
17 were noted for all the individual cardiovascular and metabolic markers with the exception of
18 FBG, with men having greater SBP and DBP and women having higher WC and TC on
19 average. Women had significantly higher mean BMI (mean = 28.50 vs. 24.50, $p < 0.05$) and
20 significantly higher mean CBR scores than men (2.38 vs. 1.68, $p < 0.01$). No clustering was
21 observed for the inflammatory marker asthma. There were no sex differences in
22 neighbourhood exposures, with similar proportions of men and women having recreation or
23 playing areas in their community and a similar mean neighbourhood disorder score (Table 1).
24 Youth comprised approximately 4% of the participants. There were also significant age
25 differences compared to adults for all the individual cardiovascular and metabolic markers,
26 including mean FBG.
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1. Weighted Descriptive Statistics and 95% CI by Sex: Jamaica Health and Lifestyle Survey 2008

Variable	Total (N= 2544)	Men (n=797)	Women(n=1747)	Youth (n=107)	Adults (n=2437)
Mean age (years)	35.23 (15.95-36.95)	34.89 (34.32-35.47)	35.37 (34.94-36.95)	16.09 (15.95-16.23)	36.60 (36.24-36.95)**
Education (%)					
< High school	28.43 (26.61-30.26)	31.44 (28.24-36.35)	27.16 (24.95-29.37)*	91.49 (86.38-96.61)	29.90 (27.99-31.81)**
≥ High school	71.56 (69.73-73.38)	68.55 (65.34-71.75)	72.84 (70.62-75.04)	8.51 (3.39-13.62)	70.09 (68.19-72.00)
Current smoker (%)	25.48 (23.72-27.24)	13.09 (11.96-14.23)	12.39 (10.96-13.89)	19.50 (10.78-28.17)	25.92 (24.15-27.69)*
Mean no. of possessions	9.34 (9.10-9.97)	9.69 (9.42-9.97)	9.19 (9.10-9.38)	9.26 (9.10-9.86)	9.28 (9.12-9.44)
Hypertension (%)	23.53 (22.01, 25.05)	22.88 (20.15, 25.61)	23.80 (21.97, 25.64)	4.67 (1.00, 8.36)	24.90 (23.30, 26.51)**
Diabetes (%)	7.44 (6.56, 8.31)	5.46 (4.15, 6.76)	8.28 (7.16, 9.40)**	0.76 (0.00, 2.27)	7.92 (6.99, 8.86)**
Mean SBP (mmHg)	121.53 (119.72-124.79)	123.75 (122.72-124.79)	120.57 (119.72-121.44)*	112.82 (110.28-115.42)	122.14 (121.43-122.86)**
Mean DBP (mmHg)	77.03 (75.84-79.19)	78.33 (77.47-79.19)	76.47 (75.84-77.11)*	70.49 (68.78-72.21)	77.49 (76.95-78.02)*
Mean WC (cm)	86.74 (86.13-87.35)	82.14 (81.27-83.00)	88.69 (87.92-89.48)*	74.77 (72.96-76.58)	87.61 (86.97-88.23)**
Mean TC (mg/dl)	4.40 (4.38-4.43)	4.25 (4.21-4.28)	4.47 (4.44-4.50)*	4.14 (4.06-4.21)	4.42 (4.39-4.45)*
Mean FBG (mM/L)	4.10 (4.02-4.18)	4.12 (3.97-4.28)	4.09 (4.01-4.18)	3.47 (3.29-3.66)	4.15 (4.07-4.23)*
Mean BMI	27.25 (26.99-27.52)	24.50 (24.09-24.87)	28.50 (28.10-28.80)*	23.19 (22.23-24.13)	27.54 (27.27-28.81)**
Self-reported asthma (%)	7.42 (3.82-9.54)	5.52 (3.82-7.17)	8.23 (6.93-9.54)	8.01 (4.72-8.46)	7.24 (6.18-8.29)
Mean CBR score	2.18 (2.12-2.24)	1.68 (1.58-1.79)	2.38 (2.31-2.46)**	1.06 (0.84-1.26)	2.26 (2.19-2.32)**
Mean Neighbourhood Disorder score [†]	11.71 (11.52-11.89)	11.35 (11.04-11.66)	11.85 (11.62-12.08)	12.33 (11.58-13.07)	11.66 (11.47-11.85)
Recreational Space Availability (%) [†]	59.04 (56.89-61.79)	59.67 (55.18-64.14)	58.78 (55.35-62.20)	55.56 (44.09-66.99)	59.28 (56.50-62.06)

* $p < 0.05$ and ** $p < 0.01$, for comparisons between men and women and between youth and adults. Youth defined as < 18 years.

[†] Based on the participant's enumeration district (ED), with a total of 113 EDs in the study. 5.05)

Abbreviations: 95% CI - 95% confidence interval; SBP – Systolic Blood Pressure; DBP- Diastolic Blood Pressure; WC – Waist Circumference; TC – Total Cholesterol; FBG – Fasting Blood Glucose; BMI – Body Mass Index; CBR – Cumulative Biological Risk

Neighbourhood Disorder Score: This comprise a composite score of the interviewers' perception of the condition of homes, streets and yards, amount of noise and air quality of neighbourhoods. Scores for each variable ranged from 1(excellent) to 4 (poor) and the overall index from 1 to 20,with a higher score indicating greater neighbourhood disorder.

Recreational Space Availability: This was based on the interviewer's perception of a) the presence of and b) walking distance to either recreational spaces, playing fields or other open spaces from a participant's home. Scores assigned were 0 (no) and 1 (yes), with a total possible maximum score of 2.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Twenty-two percent of the sample was considered to have high CBR. Figure 1 presents the total and sex-specific percentages of high CBR scores in 10-year age groups. The 35-44-year-old group had the largest percentage (31%) of high CBR scores with an approximate 20% difference in high scores between women and men. Sex differences in mean scores tapered off in older and younger age groups but remained significant at all ages.

We observed significant clustering of CBR at the neighbourhood level with an ICC of 4.6% (Figure 2). This suggests that some of the variance observed in CBR may be explained by neighbourhood level factors. Significant clustering with ICC values of over 4.0% was observed for all other biomarkers except for self-reported asthma and FBG. The highest levels of clustering were seen for both DBP and SBP. Also shown in Figure 2 are ICCs by sex and demonstrates the substantial difference in clustering by ED between in women and men (6.9% vs. 0.7%).

Neighbourhood characteristics and CBR

Table 2 presents combined and sex-specific results from the multilevel logistic regression models utilizing CBR as a dichotomous outcome. For the combined results (adjusted for age, sex and number of possessions) the likelihood of high CBR was significantly lower among respondents with greater recreational space availability (aOR = 0.75; 95% CI = 0.64, 0.94; $p < 0.05$). Controlling for the other individual level covariates such as smoking, diet or physical activity did not alter the associations and were therefore not included in models. While the overall association between neighbourhood disorder and high CBR was not statistically significant, significant interaction by sex was observed. Sex-specific results revealed a significant association between neighbourhood disorder score and high CBR (OR = 1.26; 95% CI = 1.08, 1.47; $p < 0.05$) in women but not for men (OR = 0.97; 95% CI = 0.86, 1.09), with the likelihood of high CBR increasing by 26% for each unit increase in neighbourhood disorder score among women. Results were consistent when using CBR as a continuous variable.

Table 2. Unadjusted and adjusted Odds Ratio (95% CI) for High CBR[†] Overall and Stratified by Sex (N=2,544)

Neighbourhood Characteristic	Overall CBR (95%CI)		CBR Stratified by Sex (95%CI)	
	Unadjusted	Adjusted ^{††}	Women	Men
Recreational Space Availability	0.79 (0.65-0.95)*	0.75 (0.64-0.90)*	0.82 (0.49-1.36)	0.91 (0.63-1.29)
ICC (%)	3.20	2.54	4.80	2.09
Neighbourhood Disorder Score	1.00 (0.97-1.03)	1.01 (0.98-1.04)	1.26 (1.08-1.47) *	0.97 (0.86-1.09)
ICC (%)	3.10	2.46	2.83	2.20

CBR - Cumulative Biological Risk; ICC – Intraclass Correlation Coefficient . ICC was calculated as $(V_{ED} / (V_{ED} + V_{individual})) \times 100$ where V_{ED} = variance between EDs and $V_{individual}$ = variance among individuals within EDs.

[†] High CBR was defined as at least one standard deviation above the mean score.

^{††} Adjusted for age, sex, education, no. of possessions, smoking status; stratified by sex, adjusted for age, education and no. of possessions.

* $p < 0.05$

We observed no statistically significant interaction by sex in the relationship between recreational space availability and high CBR. Inclusion of both neighbourhood exposures and individual level covariates did reduce the ICC overall. All analyses were also run with and without youth included, as well as with and without the unconventional asthma marker and there were no changes in the overall results.

DISCUSSION

CBR increased with age for both sexes and was significantly higher among women. Higher levels of recreational space availability were associated with less CBR and greater neighbourhood disorder was significantly associated with high CBR for women but not men.

Our findings are consistent with reports elsewhere of an increase in CBR with age, at least up to the 6th decade of life.[4, 24, 63] In our study, CBR increased with age for both sexes, and was consistently higher among the women across the lifespan. This is consistent with studies that have found this sex differential,[25, 64] but is a novel contribution to the existing literature given that our study population included women from as young as 15 years old, while the majority of studies examining sex differences in CBR include only older adult women We are unclear if this sex differential reflects genetic and/or gender underpinnings unique to the Jamaican context, or simply differences with unmeasured sample characteristics. Additionally, while our findings align with literature on poorer women's susceptibility to repeated exposures

1
2
3 and adaptations to stressors in more developed country contexts,[4] the scholarship on CBR in
4 developing contexts such as the Caribbean is limited. Studies in Jamaica have documented a
5 strong association between morning salivary cortisol levels and hypertension,[65] in mothers and
6 their offspring. Future studies examining sex differences in the association between cortisol,
7 other specific neuroendocrine and immune/inflammatory indicators used in the
8 operationalization of CBR may explain this observed sex differential. We were unable to assess
9 racial disparities given that Jamaicans are predominantly Black. However studies in the USA
10 have found that Black women exhibit greater CBR than Black men and more so than other racial
11 groups.[4, 10] This suggests possible epigenetic and/or environmental underpinnings. Our
12 analysis had no neuroendocrine markers, and some are recognized to produce differentially
13 higher response to stress in Blacks.[66]

22 The clustering of CBR across neighbourhoods indicates that some of the variance in CBR
23 may be due to neighbourhood environment, and more so for women.[45] Findings corroborate
24 those that have reported the stress reducing effects of recreational spaces,[67] others that have
25 demonstrated an effect of neighbourhood stress on CBR,[19, 20] and add to the work examining
26 the differential impact of such contextual stress by sex. Research has shown that women
27 subjectively experience more stress than men and consistently report more physical and
28 somatoform symptoms, and show higher stress vulnerability.[31-34] Neighborhood disorder
29 may be a marker of more deprived community environments, whereby healthy food access is
30 limited [68, 69] and may lead to higher CBR. [25] Disorder and the stress it may induce could
31 also lead to differences in coping, particularly among women. Fernandez et al,[70] found that the
32 engagement - when a person actively confronts a stressor (eg, "I tackle the problem head on.")
33 and disengagement - when a person avoids a stressor (eg, "I try not to think about the problem")
34 coping styles of African American women, measured by using the Coping Strategies Inventory
35 Short Form, were associated with CBR levels. Disorder may also be related to physical activity.
36 Our disorder marker included condition of the streets, which may impact even utilitarian physical
37 activity [71, 72] and thereby CBR levels. Furthermore, our marker of neighbourhood disorder
38 included air quality, which may also directly impact CBR.[73] However, our literature review
39 has not revealed evidence supporting greater exposure of women versus men to poorer air quality
40 in residential environments. Future behavioural studies exploring similar associations may help
41 identify additional covariates which can inform sex-specific interventions for reducing CBR
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59

1
2
3 among Jamaicans. Our finding that greater neighbourhood disorder was significantly associated
4 with high CBR for women but not men may reflect neighbourhood disorder serving as a proxy
5 for neighbourhood SES.[45] While this finding aligns with a few others on poorer women's
6 susceptibility to repeated exposures and adaptations to stressors in more developed country
7 contexts,[4, 13, 74] similar scholarship on CBR in developing contexts such as the Caribbean is
8 limited.
9

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

There are strengths and potential limitations of this study. Strengths include the fact that this is the first study to demonstrate sex differences in CBR in a small island developing country, and the first to examine neighbourhood influences on CBR in this context. On the other hand, there are a number of potential limitations. Firstly, cross-sectional data were used which limits our ability to make inferences regarding causation or say definitively whether our findings show age trends. The population in each age group examined is the surviving population from cohorts born earlier (a selectivity bias), and may be a confounder for the pattern seen in our results. It also may not be possible to generalize our results to other Black populations. Secondly, we are also unclear if the observed sex differential reflects genetic, environmental and/or gender underpinnings unique to the Jamaican context, or simply differences with unmeasured sample characteristics. For example, our results suggest an independent effect for cumulative biological risk neighbourhood disorder-level context in women, but not for men. However, the analysis lacked sex specific individual level data such as sex-specific exposure and physiological and/or neuro-hormonal changes. Individual-level socioeconomic status effects could be more apparent than aggregate neighbourhood disorders or at the very least that they would provide independent or confounded impacts for cumulative biological risk. Additionally, there is no agreed gold standard for the operationalisation of CBR or AL. For example, our study included only 7 markers compared with others that used between 9 and 11 biomarkers.[7, 74] In particular, as stated previously we had no individual-level neuroendocrine or immune biomarkers and may have missed other important associations. Of note, studies in Jamaica have documented a strong association between morning salivary cortisol levels and hypertension in mothers and their offspring.[62] Future studies examining sex differences in the association between cortisol, other specific neuroendocrine and immune/inflammatory indicators used in the operationalisation of CBR may explain this observed sex differential. Another limitation is that we did not assess the use of medication for HTN, DM or TC as was done in other studies.[4, 24]

1
2
3 It is possible medication use may have decreased CBR due to a shift of biomarkers below the
4 high risk cut points or increased it among the young, for whom taking medication would indicate
5 that some systemic dysregulation has already occurred.[4] Additionally, the neighbourhood was
6 defined as an ED, many of which are heterogeneous. It is quite possible that important
7 geographic effects may have been misclassified or not captured. Neighbourhood characteristics
8 were subjectively assessed by interviewers, increasing the possibility of information bias. We
9 also had no information on the interrater reliability of neighborhood assessments, given the
10 existing nature of the data and timeframe since data collection. While we assume, given the
11 information on training of interviewer perceptions, that the reliability was high, there was no way
12 to test this. Finally, we have no data on lifetime history or risk factors (e.g. trauma or abuse,
13 childhood socioeconomic status, birthweight or childhood nutrition) that may also impact CBR
14 in adulthood.
15
16
17
18
19
20
21
22
23

24 Targeting neighbourhood change is feasible and may not only improve neighbourhood
25 quality but also exert a small, sustained improvement in the health of women in those
26 neighbourhoods. From a public health perspective, such structural changes offer an effective
27 alternative method for reducing health disparities. In Jamaica we have found significant clustering
28 at the neighbourhood level in obesity and significant increase in obesity among women in the
29 absence of supermarkets and markets, suggesting the need for greater emphasis on policies,
30 programmes and interventions that are focused on the neighbourhood-level effects.[75] This
31 study delves even deeper, considering potential biologic impacts that may occur irrespective of
32 women's individual behaviours, and suggests policymakers and clinicians implement
33 programmes focusing on earlier monitoring of biologic stress before NCDs develops.
34
35
36
37
38
39
40

41 The results from this study also strengthen the case for multidisciplinary local and
42 regional health research that is sensitive to sex differences in exposures and vulnerabilities that
43 likely contribute to CBR differences and related health outcomes such as NCDs. The higher
44 CBR score among women in tandem with the higher ICC levels for the women versus men by
45 EDs, suggests that gender specific factors must be considered in the development of a
46 programme of research on CBR in the Jamaican health context.[45] The sex differences in CBR
47 clustering by ED also suggests the need for multilevel models that address the possible
48 gendered vulnerabilities and exposures within the context of objective measurements of
49 neighbourhood disorder and other neighbourhood level factors.
50
51
52
53
54
55
56
57
58
59
60

STATEMENTS

Contributors CCM, IG and KT conceived the study. LG and PLA geocoded the data. CCM, EM, KT, and NYC analysed the data. CCM wrote the manuscript. MTR, SM, DF, GGS, RW and KT edited the paper. All authors approved the final manuscript.

Funding The JHLS II was supported by the National Health Fund, Jamaica.

Competing interests None declared

Ethics approval The JHLS II was approved by the Ministry of Health, Jamaica and the University Hospital of the West Indies. No additional ethical approval was necessary for this secondary data analysis.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

REFERENCES

1. Beaglehole R, Bonita R, Horton R, *et al.* Priority actions for the non-communicable disease crisis. *Lancet* 2011; 377(9775):1438-1447.
2. McEwen BS, Stellar E. Stress and the individual: mechanisms leading to disease. *Arch Intern Med* 1993; 153(18):2093.
3. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998; 338(3):171.
4. Geronimus AT, Hicken M, Keene D, *et al.* "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *Am J Public Health* 2006; 96(5):826-33.
5. Borrell LN, Dallo FJ, Nguyen N. Racial/ethnic disparities in all-cause mortality in US adults: the effect of allostatic load. *Public Health Rep* 2010; 125(6):810.
6. Seeman TE, Singer BH, Rowe JW, *et al.* Price of adaptation--allostatic load and its health consequences. MacArthur studies of successful aging. *Arch Intern Med* 1997; 157(19): 2259-68.
7. Beckie TM. A Systematic Review of Allostatic Load, Health, and Health Disparities. *Biol Res Nurs* 2012;14(4):311-346.
8. McEwen B, Seeman T. Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. *Ann N Y Acad Sci* 1999; 896(1):30-47.
9. Seeman TE, McEwen BS. Social environment characteristics and neuroendocrine function: the impact of social ties and support on neuroendocrine regulation. *Psychosom Med* 1996;58(5):459-71
10. Bird CE, Seeman T, Escarce JJ *et al.* Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *J Epidemiol Community Health* 2010; 64(10):860-5.
11. King KE, Morenoff JD, House JS. Neighborhood context and social disparities in cumulative biological risk factors. *Psychosom Med* 2011;73(7):572-579.
12. Schulz AJ, Mentz G, Lachance L, *et al.* Associations between socioeconomic status and allostatic load: effects of neighborhood poverty and tests of mediating pathways. *Am J Public Health* 2012;102(9):1706-1714.

13. Merkin S, Basurto-Dávila R, Karlamangla A, *et al.* Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of US adults: NHANES III. *Ann Epidemiol* 2009;19(3):194.
14. Robinson AI, Carnes F, Oreskovic NM. Spatial analysis of crime incidence and adolescent physical activity. *Prev Med* 2016; 85:74-7.
15. Sallis JF, Bowles HR, Bauman A, *et al.* Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;36(6):484-90.
16. Swinburn BG, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999;29(6 Pt 1):563-70.
17. Gordon-Larsen P, Nelson MC, Page P, *et al.* Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics* 2006;117(2):417-24.
18. Ross C, Mirowsky J. Neighborhood disadvantage, disorder, and health. *J Health Soc Behav* 2001;43(2):258-276.
19. Theall KP, Brett ZH, Shirtcliff EA, *et al.* Neighborhood disorder and telomeres: connecting children's exposure to community level stress and cellular response. *Soc Sci Med* 2013; 85:50-8.
20. Hosseini F, Adha N, Zainol R, *et al.* Neighborhood-Level Stress and Circadian Cortisol: A Systematic Review and Meta-Analysis. *Iran J Public Health* 2014;43(10):1324-34.
21. Stafford M, Cummins S, Ellaway A, *et al.* Pathways to obesity: identifying local, modifiable determinants of physical activity and diet. *Soc Sci Med* 2007; 65(9):1882-1897.
22. Harrington DW, Elliott SJ. Weighing the importance of neighbourhood: a multilevel exploration of the determinants of overweight and obesity. *Soc Sci Med* 2009;68(4):593-600.
23. Diez Roux AV, Mujahid MS, Hirsch JA, *et al.* The impact of neighborhoods on CV risk. *Glob Heart* 2016;11(3): 353-363.
24. Yang Y, Kozloski M. Sex differences in age trajectories of physiological dysregulation: inflammation, metabolic syndrome, and allostatic load. *J Gerontol A Biol Sci Med Sci* 2011;66(5):493-500.

- 1
- 2
- 3 25. Kusano Y, Crews DE, Iwamoto A, *et al.* Allostatic load differs by sex and diet, but not
- 4 age in older Japanese from the Goto Islands. *Ann Hum Biol* 2015;1-8.
- 5
- 6 26. Juster R.-P, Lupien S. A sex-and gender-based analysis of allostatic load and physical
- 7 complaints. *Gen Med* 2012;9(6):511-523.
- 8
- 9
- 10 27. Lloyd-Jones DM, Wilson PWF, Larson MG, *et al.* Framingham risk score and prediction
- 11 of lifetime risk for coronary heart disease. *Am J Cardiol* 2004;94(1):20-24.
- 12
- 13 28. Eskes T, Haanen C. Why do women live longer than men? *Eur J Obstet Gynecol Reprod*
- 14 *Biol* 2007;133(2):126-133.
- 15
- 16 29. Schuurs AHW, Verheul HAM. Effects of gender and sex steroids on the immune
- 17 response. *J Steroid Biochem* 1990;35(2):157-172.
- 18
- 19 30. Stafford M, Cummins S, Macintyre S, *et al.* Gender differences in the associations
- 20 between health and neighbourhood environment. *Soc Sci Med* 2005;60(8):1681-92.
- 21
- 22 31. Barnett R, Biener L, Baruch G. Gender and stress. The Free Press, 1987.
- 23
- 24 32. Bebbington P, Dunn G, Jenkins R, *et al.* The influence of age and sex on the prevalence
- 25 of depressive conditions: report from the National Survey of Psychiatric Morbidity. *Int*
- 26 *Rev Psychiatry* 2003;15(1-2):74-83.
- 27
- 28 33. Kessler R, Brown R, Broman C. Sex differences in psychiatric help-seeking: Evidence
- 29 from four large-scale surveys. *J Health Soc Behav* 1981:49-64.
- 30
- 31 34. Kessler R, McLeod J. Sex differences in vulnerability to undesirable life events. *Am*
- 32 *Sociol Rev* 1984:620-631.
- 33
- 34 35. LaVeist TA, Wallace JM, Jr. Health risk and inequitable distribution of liquor stores in
- 35 African American neighborhood. *Soc Sci Med* 2000;51(4):613-7.
- 36
- 37 36. Lean M, Han T, Morrison C. Waist circumference as a measure for indicating need for
- 38 weight management. *BMJ* 1995;311(6998):158.
- 39
- 40 37. Theall KP, Drury SS, Shirtcliff EA. Cumulative Neighborhood Risk of Psychosocial
- 41 Stress and Allostatic Load in Adolescents. *Am J Epidemiol* 2011;176(suppl 7): S164-
- 42 S174.
- 43
- 44 38. Chum A, O'Campo P. Cross-sectional associations between residential environmental
- 45 exposures and cardiovascular diseases. *BMC Public Health*, 2015;15(1):438.
- 46
- 47 39. Wilks R, Younger N, Tulloch-Reid M, *et al.* Jamaica Health and Lifestyle Survey 2007-
- 48 8. Available from: http://www.mona.uwi.edu/reports/health/JHLSII_final_may09.pdf.
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

- 1
- 2
- 3
- 4 40. Abdulkadri AO, Cunningham-Myrie C, Forrester T. Economic burden of diabetes and
- 5 hypertension in CARICOM states. *Soc Econ Stud* 2009;58 (3 &4):175-197.
- 6
- 7 41. Hospedales CJ, Samuels T, Cummings R, *et al.* Raising the priority of chronic
- 8 noncommunicable diseases in the Caribbean. *Rev Panam Salud Pública* 2011;30(4):393-
- 9 400.
- 10
- 11 42. Statistical Institute of Jamaica 2015. Available from:
- 12 http://statinja.gov.jm/living_conditions_poverty.aspx. (accessed June 15, 2018)
- 13
- 14
- 15 43. Austin-Broos, D. Urban life in Kingston Jamaica: the culture and class ideology of two
- 16 neighborhoods. Routledge, 2017.
- 17
- 18 44. Lowe GA, Lipps G, Gibson RC, *et al.* Neighbourhood factors and depression among
- 19 adolescents in four Caribbean countries. *PloS One* 2014; 9(4):e95538.
- 20
- 21
- 22 45. Mullings JA, McCaw-Binns AM, Archer C, *et al.* Gender differences in the effects of
- 23 urban neighborhood on depressive symptoms in Jamaica. *Rev Panam Salud Pública*
- 24 2013;34(6): 385-92.
- 25
- 26
- 27 46. Cunningham-Myrie CA, Theall KP, Younger NO, *et al.* Associations between
- 28 neighborhood effects and physical activity, obesity, and diabetes: The Jamaica Health
- 29 and Lifestyle Survey 2008. *J Clin Epidemiol* 2015;68(9):970-8.
- 30
- 31
- 32 47. Bernard P, Charafeddine R, Frohlich KL, *et al.* Health inequalities and place: a
- 33 theoretical conception of neighbourhood. *Soc Sci Med* 2007;65(9):1839-1852.
- 34
- 35
- 36 48. Sampson R, Morenoff J. Spatial (Dis)Advantage and Homicide in Chicago
- 37 Neighborhoods, in *Spatially Integrated Social Science*, M. Goodchild and D. Janelle,
- 38 Editors. 2004, Oxford: New York, NY. 145-170.
- 39
- 40
- 41 49. Krieger N. Methods for the scientific study of discrimination and health: an ecosocial
- 42 approach. *Am J Public Health* 2012;102(5):936-944.
- 43
- 44
- 45 50. Barnes PJ. Immunology of asthma and chronic obstructive pulmonary disease. *Nat Rev*
- 46 *Immunol* 2008;8(3):183-92.
- 47
- 48 51. Roth GA, Fihn SD, Mokdad AH, *et al.* High total serum cholesterol, medication coverage
- 49 and therapeutic control: an analysis of national health examination survey data from eight
- 50 countries. *Bull World Health Organ* 2011;89(2):92-101.
- 51
- 52
- 53 52. World Health Organization. Definition and diagnosis of diabetes mellitus and
- 54 intermediate hyperglycaemia: report of a WHO/IDF Consultation Report. 2006.
- 55
- 56
- 57
- 58
- 59
- 60

- 1
- 2
- 3 53. Koebnick C, Black MH, Wu J, *et al.*, High blood pressure in overweight and obese youth:
4 implications for screening. *J Clin Hyperens (Greenwich)* 2013;15(11):793-805.
- 5
- 6 54. Sampson RJ, Raudenbush SW. Systematic social observation of public spaces: A new
7 look at disorder in urban neighborhoods. *Am J Sociol* 1999; 105(3):603-651.
- 8
- 9 55. Odgers CL, Caspi A, Bates CJ, *et al.* Systematic social observation of children's
10 neighborhoods using Google Street View: a reliable and cost-effective method. *J Child*
11 *Psychol Psychiatry* 2012;53(10):1009-1017.
- 12
- 13 56. Ross CE, Jang SJ. Neighborhood disorder, fear, and mistrust: The buffering role of social
14 ties with neighbors. *Am J Community Psychol* 2000;28(4):401-420.
- 15
- 16 57. Sampson RJ, Raudenbush SW. "Seeing disorder: Neighborhood stigma and the social
17 construction of "broken windows". *Soc Psychol Q* 2004;67(4):319-342.
- 18
- 19 58. Duneier M. *Sidewalk*. Macmillan, 1999.
- 20
- 21 59. Harcourt BE. *Illusion of order: The false promise of broken windows policing*. Harvard
22 University Press, 2009.
- 23
- 24 60. Raudenbush SW, Bryk AS. *Hierarchical linear models: Applications and data analysis*
25 *methods*. Sage Publications, Incorporated Vol. 1, 2001.
- 26
- 27 61. Snijders TAB, Bosker RJ. *Multilevel analysis: an introduction to basic and advanced*
28 *multilevel modeling*. Thousand Oaks, Calif. ; London: SAGE, 1999.
- 29
- 30 62. Merlo J, Chaix B, Ohlsson H, *et al.* A brief conceptual tutorial of multilevel analysis in
31 social epidemiology: using measures of clustering in multilevel logistic regression to
32 investigate contextual phenomena. *J Epidemiol Community Health* 2006;60(4):290-7.
- 33
- 34 63. Crimmins EM, Johnston M, Hayward M, *et al.* Age differences in allostatic load: an
35 index of physiological dysregulation. *Exp Gerontol* 2003;38(7):731-734.
- 36
- 37 64. Mair CA, Cutchin MP, Peek MK. Allostatic load in an environmental riskscape: The role
38 of stressors and gender. *Health Place* 2011;17(4):978-987.
- 39
- 40 65. Boyne MS, Woolard A, Phillips DI, *et al.* The association of hypothalamic-pituitary-
41 adrenal axis activity and blood pressure in an Afro-Caribbean population.
42 *Psychoneuroendocrinology* 2009;34(5):736-42.
- 43
- 44 66. Chong RY, Uhart M, McCaul ME, *et al.* Whites have a more robust hypothalamic-
45 pituitary-adrenal axis response to a psychological stressor than blacks.
46 *Psychoneuroendocrinology* 2008;33(2):246-54.
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

- 1
2
3 67. Stigsdotter UK, Ekholm O, Schipperijn J, *et al.* Health promoting outdoor environments--
4 associations between green space, and health, health-related quality of life and stress
5 based on a Danish national representative survey. *Scand J Public Health* 2010;38(4):411-
6 7.
7
8
9
10 68. Bower KM, Thorpe RJ, Jr., Rohde C, *et al.* The intersection of neighborhood racial
11 segregation, poverty, and urbanicity and its impact on food store availability in the
12 United States. *Prev Med* 2014;58:33-9.
13
14
15 69. Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the
16 location and type of food stores. *Am J Public Health* 2006;96(2): 325-331.
17
18 70. Fernandez CA, Loucks EB, Arheart KL, *et al.* Evaluating the Effects of Coping Style on
19 Allostatic Load, by Sex: The Jackson Heart Study, 2000-2004. *Prev Chronic Dis*
20 2015;12:E165.
21
22
23 71. Lee C, Ory MG, Yoon J, *et al.* Neighborhood walking among overweight and obese
24 adults: age variations in barriers and motivators. *J Community Health* 2013;38(1):12-22.
25
26
27 72. Miles R, Panton LB, Jang M, *et al.* Residential context, walking and obesity: two
28 African-American neighborhoods compared. *Health Place* 2008;14(2):275-86.
29
30
31 73. Clougherty JE, Kubzansky LD. A framework for examining social stress and
32 susceptibility to air pollution in respiratory health. *Environ Health Perspect* 2009;117(9):
33 1351-8.
34
35
36 74. Hickson DA, Diez Roux AV, Gebreab SY, *et al.* Social Patterning of Cumulative
37 Biological Risk by Education and Income Among African Americans. *Am J Public*
38 *Health* 2012;102(7):1362-1369.
39
40
41 75. Myrie CA. An Exploration of Geographic Variation in Obesity, Its Key Risk Factors and
42 Comorbidities. Are There Opportunities for Tailoring Public Health Interventions?
43 Secondary Analysis of The Jamaica Health and Lifestyle Survey 2008 (JHLS II)
44 [dissertation]. Mona, Jamaica; University of the West Indies; 2018. 371 p.
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 **Figure 1** Proportion High CBR[†] score by age and sex

4 CBR – Cumulative Biological Risk

5 [†]High CBR was defined as at least one standard deviation above the mean score.

6 *p < 0.01 and **p < 0.0001 comparing sex differences within each age group
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1
2
3 **Figure 2** Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High
4 Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.
5

6 CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure;
7 WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body
8 Mass Index* High CBR was defined as at least one standard deviation above the mean score.

9 ** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma,
10 DBP > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and
11 BMI \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation
12 above the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and
13 DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for
14 age, sex, and BMI.
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

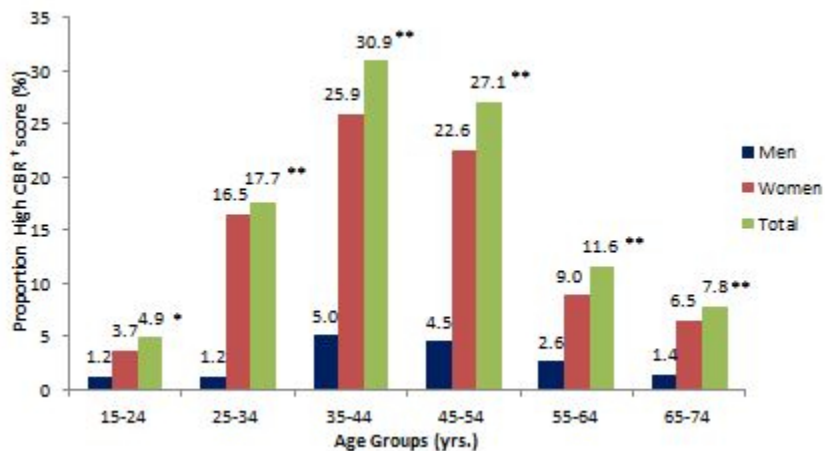


Figure 1 Proportion High CBR⁺ score by age and sex CBR – Cumulative Biological Risk †High CBR was defined as at least one standard deviation above the mean score. *p < 0.01, ** and ***p < 0.0001 comparing sex differences within each age group

35x19mm (300 x 300 DPI)

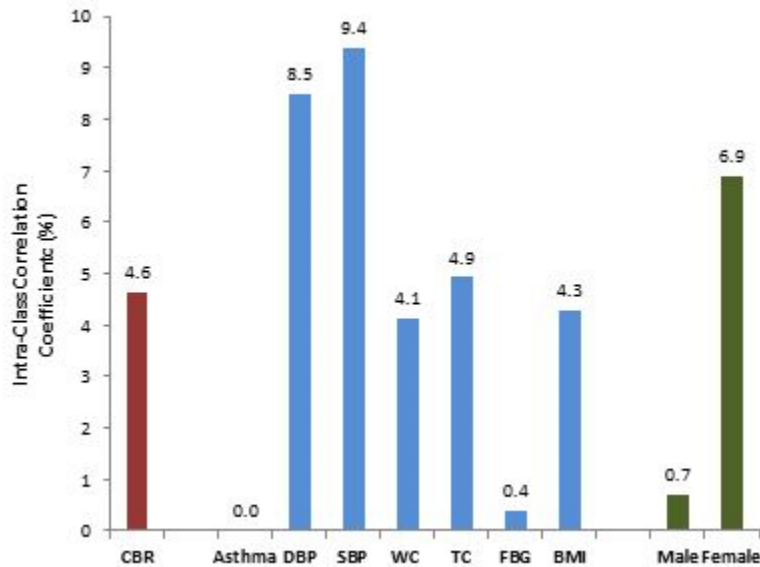


Figure 2 Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.

CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure; WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body Mass Index* High CBR was defined as at least one standard deviation above the mean score.

** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma, DBP > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and BMI \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for age, sex, and BMI.

33x24mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-9
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	8-9
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	8
		(e) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6-8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Neighbourhood Characteristics and Cumulative Biological Risk: Evidence from the Jamaica Health and Lifestyle Survey 2008

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-021952.R2
Article Type:	Research
Date Submitted by the Author:	11-Aug-2018
Complete List of Authors:	Cunningham-Myrie, Colette; University of the West Indies at Mona Faculty of Medical Sciences, Community Health and Psychiatry Mabile, Emily; Louisiana Office of Public Health, Bureau of Family Health Govia, Ishtar; University of the West Indies, Caribbean Institute for Health Research Younger, Novie; University of the West Indies, Caribbean Institute for Health Research Tulloch-Reid, Marshall; The University of the West Indies , Caribbean Institute for Health Research McFarlane, Shelly ; University of the West Indies, Caribbean Institute for Health Research Francis, Damian; University of the West Indies, Caribbean Institute for Health Research Gordon-Strachan, Georgiana; University of the West Indies, Caribbean Institute for Health Research Wilks, Rainford; University of the West Indies, Caribbean Institute for Health Research Greene, Lisa-Gaye; University of the West Indies, Mona GeoInformatics Institute Lyew-Ayee, Parris; University of the West Indies, Mona GeoInformatics Institute Theall, Katherine; Tulane University, Global Community Health and Behavioral Sciences
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	developing country, cumulative biological risk, women, neighbourhoods

SCHOLARONE™
Manuscripts

1
2
3 **Neighbourhood Characteristics and Cumulative Biological Risk: Evidence from the Jamaica**
4 **Health and Lifestyle Survey 2008**
5
6
7

8 Colette Andrea Cunningham-Myrie ¹, Emily Mabile MPH ², Ishtar Govia PhD³, Novie O
9 Younger PhD³, Marshall Kerr Tulloch-Reid DSc³, Shelly McFarlane PhD³, Damian Francis
10 MSc³, Georgiana Gordon-Strachan PhD³, Rainford Wilks DM³, Lisa-Gaye Greene BA⁴, Parris
11 Lyew-Ayee PhD⁴, Katherine P Theall PhD⁵
12
13
14
15

16
17 ¹Department of Community Health and Psychiatry, University of the West Indies, Mona,
18 Jamaica
19

20 ²Louisiana Department of Health, Office of Public Health, Bureau of Family Health, USA
21

22 ³Caribbean Institute for Health Research, University of the West Indies, Mona, Jamaica
23

24 ⁴Mona GeoInformatics Institute, University of the West Indies, Mona, Jamaica
25

26 ⁵Department of Global Community Health and Behavioral Sciences, School of Public Health and
27 Tropical Medicine, Tulane University, USA
28
29

30
31 Corresponding author:

32 Dr. Katherine P. Theall
33

34 Department of Global Community Health and Behavioral Sciences
35

36 Tulane University School of Public Health and Tropical Medicine
37

38 1440 Canal Street, Suite 2300
39

40 New Orleans, LA 70112
41

42 Telephone: (504)988-4535
43

44 Email : ktheall@tulane.edu
45

46 Word count: 4346
47
48
49

50 Keywords: Cumulative Biological Risk, women, neighbourhoods, developing country
51
52
53
54
55
56
57
58
59

ABSTRACT

Objective To examine whether neighbourhood characteristics are associated with Cumulative Biological Risk (CBR) and sex differences in CBR in a nationally representative sample in Jamaica, a small island developing country with increasing prevalence of noncommunicable diseases (NCDs).

Design Cross-sectional study

Setting A population-based survey, the Jamaica Health and Lifestyle Survey 2008 (JHLS II) recruited persons at their homes over a four-month period from all 14 parishes and 113 neighbourhoods defined as Enumeration Districts (EDs).

Participants 2544 persons aged 15-74 years old from the 2008 Jamaica Health and Lifestyle Survey (JHLS II), who completed interviewer-administered questionnaires and had biomarkers assessed, and whose home addresses could be reliably geocoded.

Primary outcome A summary measure CBR was created using 7 markers - systolic and diastolic blood pressure readings, waist circumference, body mass index, total cholesterol, fasting blood glucose levels and self-reported asthma. Weighted multilevel models examined clustering, using the Intraclass Correlation Coefficient (ICC), of CBR across neighbourhoods and the impact of neighbourhood characteristics (recreational space availability and neighbourhood disorder) on CBR.

Results Women had significantly higher mean CBR scores than men across all age groups. There was significant clustering of CBR by ED, and among women versus men (ICC F= 6.9%, M= 0.7%). Women living in more disordered neighbourhoods were 26% more likely to have high CBR as those in less disordered ones (aOR=1.26, 95% CI=1.08-1.47; p <0.05). Individuals living in EDs with greater recreational space availability were 25% less likely to have a high CBR (aOR=0.75, 95% CI=0.64-0.90; p <0.05).

Conclusions Policymakers in Jamaica should pay greater attention to neighbourhood factors such as recreational space availability and neighbourhood disorder that may contribute to CBR in any effort to curtail the epidemic of NCDs.

Strengths and limitations of this study

- This study provided a large sample size representative of Jamaicans 15 to 74 years.
- The study examines the role of neighbourhood context, including factors beyond socioeconomic status, on biologic stress in a middle-income country context.
- The study included only 7 markers to assess Cumulative Biological Risk (CBR) and had no neuroendocrine or immune biomarkers based on data unavailability.
- The neighbourhood was defined as an Enumeration District, many of which are heterogeneous, making it possible that important geographic effects may have been misclassified or not captured.
- Neighbourhood characteristics were subjectively assessed by interviewers, increasing the possibility of information bias.

INTRODUCTION

The global epidemic of the noncommunicable diseases (NCDs) has resulted in continued research efforts to understand and ameliorate the antecedents, and there is accumulating evidence suggesting that cumulative biologic risk (CBR) is associated with NCDs and may be an early warning sign for later negative health outcomes. [1] CBR is often operationalised as allostatic load (AL), defined as the cumulative wear and tear on physiological systems and organs due to chronic stress.[2-4] It has been posited as a key mechanism in the association between early life adversity and later health outcomes, including illness and mortality,[5] and is an important pathway that may be a link to socioeconomic and racial/ethnic health disparities.[4] The original operationalization of AL involved a count-based index from 10 markers of multisystem biological dysregulation[6] [7]that fall under two main categories: a) primary mediators, or substances the body releases in response to stress and disruption in hypothalamic-pituitary-adrenocortical (HPA) and sympathetic-adrenocortical (SAM) activity such as norepinephrine and cortisol, and b) secondary outcomes such as elevated blood pressure and body mass index (BMI), which are effects that result from the actions of the primary mediators.[8, 9] From a population health perspective, it is important to identify potential factors amenable to change that may impact CBR on a larger scale.

The neighbourhood environment may play a key direct and indirect role in shaping CBR through dysregulation of the physiologic and stress response systems and potential behavioral and health outcomes,[10-12] as well as in the production of racial and socioeconomic disparities in outcomes.[13] Neighbourhoods may impact CBR through their impact on health behaviors, e.g., neighbourhood safety has been linked to a lower likelihood of engaging in physical activity and an increased risk of obesity. [14-16] Social conditions such as high crime and neighbourhood

1
2
3 disorder, as well as poor built environments (e.g., inadequate access to healthy foods and physical
4 and recreational activity spaces) are all too common in socioeconomically disadvantaged
5 neighbourhoods. [17]
6
7

8 Beyond socioeconomic status, however, few studies have examined additional
9 neighbourhood stressors and their impact on CBR or markers of CBR. Neighbourhood disorder,
10 characterized by high levels of violence, low social control, and poor built environments, [18] may
11 be an important factor in the production of stress and CBR, even above and beyond the impact on
12 health behaviors. Neighbourhood disorder has been linked to markers of biologic stress in both
13 children [19] and adults. [20] It is also important to examine specific aspects of disordered
14 neighbourhoods, such as built environments like physical activity or recreational space
15 availability. Availability of spaces to be physically active has been linked to NCDs like obesity
16 [21, 22] and NCD risk factors. [23] Neighbourhood conditions and their association with CBR,
17 however, have not been examined in developing country contexts.
18
19
20
21
22
23
24
25

26 The vulnerability to social environmental stress, its impact on CBR and subsequent health
27 risk may also differ according to sex and race. Few studies exist comparing sex differences in
28 CBR, and whatever sex differences exist may vary from country to country. For example, in a U.S.
29 nationally representative study including individuals aged 17 years and older, women had a higher
30 AL than men, with larger differences after menopause.[24] However among Japanese 55 to 89
31 years old, women had lower AL than men.[25] Another study of mostly White workers aged 27 to
32 65 years of age in Montreal Canada, suggested that sex differences in AL may be more closely
33 related to gender roles than biological sex, per se.[26] Empirical evidence for sex differences in
34 CBR or across individual systems remains limited,[24, 27-29] particularly in a developing country
35 context. Furthermore, the differential effect of neighbourhood conditions on CBR by sex or gender
36 has been seldom investigated. This is despite existing evidence of a differential effect of the
37 neighbourhood environment on women vs. men, due to a hypothesized increased susceptibility
38 and/or exposure of women to neighbourhood effects. [30] Among adults, research has shown that
39 women subjectively experience more stress than men and consistently report more physical and
40 somatoform symptoms, and show higher stress vulnerability.[31-34] [31-34] With respect to race,
41 in the US, Blacks have been shown to have higher rates of CBR or AL,[4, 13] live in more deprived
42 neighbourhoods,[35] compared to Whites, and Black women have shown the most consistently
43 elevated levels of AL across age groups.[36]
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Neighbourhood socioeconomic status, [10, 13] and conditions have been positively
4 associated with the accumulation of biological risk in developed countries. [37, 38] but limited
5 work has been done in developing countries. Jamaica provides a unique environment for
6 examining neighbourhood influences on CBR and differences between Black women and men in
7 a developing country, given the island has a predominantly (94%) Black population with
8 increasing prevalence of NCDs.[39] The epidemiological profile of NCDs in Jamaica mirrors that
9 of many small island developing states having undergone an epidemiological transition and are
10 struggling to deal with the high cost of NCD management.[40, 41] Furthermore, increasing levels
11 of poverty in the country, [42] coupled with high levels of neighbourhood-level social stratification
12 and potential consequences of stratification (e.g., crime, discrimination) in Jamaica[43] may be
13 contributing significantly to rates of NCD and risk factors like CBR. However, few studies have
14 examined more distal exposures, with the exception of a handful focused on mental health
15 outcomes [44, 45] and our previous secondary analysis of the National Jamaica Health and
16 Lifestyle Surveys (JHLS) II [46], which revealed that differences in obesity-related outcomes may
17 be partially explained by characteristics of the neighbourhood environment. We found an impact
18 of neighbourhood infrastructure on overweight/obesity that differed by sex, with a significant
19 association in men but not women.
20
21
22
23
24
25
26
27
28
29
30
31

32 Within the contemporary Jamaican and US contexts, there are key indicators of social
33 stratification that set men and women apart (e.g., single parenthood, household headship, and
34 poverty) and that are related to differences in the prevalence and incidence of physical and mental
35 health outcomes. Examination of differences within otherwise homogenous geographic or social
36 communities provides a more organic understanding of the theories of fundamental cause in terms
37 of “spatial externalities” (e.g., economic policies made at the community level) which may allow
38 for better design of effective population level interventions.[47, 48] In the proposed study, we
39 aimed to examine the production of biologic stress in a seemingly homogenous racial population
40 and how such structural factors may be embodied,[49] providing a comprehensive socioecological
41 framework that will inform treatment and prevention efforts in middle income countries like
42 Jamaica as well as those aimed at reducing disparities in the US by targeting differences within
43 groups.[46][37, 38]
44
45
46
47
48
49
50
51
52

53 Through a secondary analysis of the JHLS II dataset, we examined the relation between
54 neighbourhood conditions—specifically, neighbourhood disorder and availability of recreational
55
56
57
58
59
60

spaces—and CBR in Jamaica, as well as differences by sex. We hypothesized that Jamaican females would have higher CBR than their male counterparts and that CBR would be associated with neighbourhood environments, although differentially by sex. We have chosen to use the terminology CBR instead of AL, given our survey data does not include measures of primary stress mediators.

MATERIALS AND METHODS

Study design and population

Data were obtained from the JHLS II dataset, a nationally representative cross-sectional survey conducted among 2897 individuals aged 15-74 years old between November 2007 and March 2008. The JHLS II captured health information through i) an interviewer administered survey, ii) anthropometry, and iii) bio-specimens for blood cholesterol and glucose via the finger-prick method utilizing point-of-care instruments for testing. The field team was trained in interview techniques and all were certified to conduct anthropometry and other biomedical assessments. Recruitment was conducted by random selection of clusters (enumeration districts) using a probability proportional to the size of the population within all parishes in Jamaica. Within each cluster, every 10th household was systematically selected from a randomly selected starting point, with a single individual being chosen to represent each household. Of those sampled, 353 participants did not have complete biomedical data and were excluded from the analyses, leaving a final sample of 2544 individuals analyzed. Further details on sampling methods and procedures followed to collect biomedical measures are found in the technical report. [39]

Patient and public involvement

Study participants were generally residents of communities and no patients were involved in the study. The study participants were not involved in the design, recruitment or the conduct of the study. The study findings will be disseminated to the Ministry of Health, Jamaica and general public, including the study participants.

Measures

Individual-level measures

1
2
3 The primary outcome CBR was based on a summary score from 7 markers based on availability
4 of data. Markers included systolic blood pressure (SBP) and diastolic blood pressure (DBP), waist
5 circumference (WC), body mass index (BMI), total cholesterol (TC) levels and fasting blood
6 glucose (FBG) levels. Given the absence of an inflammatory marker in the dataset, self-reported
7 asthma was added, given that it is an inflammatory condition. [50] It has been used in previous
8 studies assessing CBR. [37]

9
10 Each marker had a clinically defined age-specific cut-off for high risk. Adult cut-off values
11 were: > 130 mmHg for SBP, > 85 mmHg for DBP, ≥ 94 cm for male and ≥ 80 cm for female WC,
12 [36] ≥ 25 kg/m² for BMI, > 6.2 mM/L for TC levels [51] and ≥ 110 mg/dL (6.1mmol/L) for FBG
13 levels. [52] CBR was examined as both a continuous and a dichotomous variable. High CBR was
14 defined as at least one standard deviation above the mean score and a dichotomous score assigned
15 for high or low risk (1 or 0 respectively). Scores were summed to create the total CBR score with
16 a possible maximum score of 7 (self-reported asthma included). Youth (< 18 years) were defined
17 as being “at risk” with regard to each biomarker if their value was greater than 1 standard deviation
18 above the mean for their age and sex or if they had a value at/above the adult cutoff value. The
19 exception was SBP and DBP, with high risk cut-points defined as being greater than or equal to
20 the 94th percentile for age, sex, and BMI. [53]

21
22 Covariates such as age, sex, education level (< than versus \geq high school) and smoking
23 status (currently smoke any form of tobacco) were also examined. Further details on how these
24 variables were assessed can be found in the technical report. [39]

25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 *Household measures*

40
41 The number of possessions in a household from a list of twenty items (including car ownership),
42 was used as a proxy for reflecting socioeconomic status (SES). Household crowding was also
43 examined as a potential confounder, defined as both more than one person per habitable room as
44 well as the average number of individuals per habitable room. A complete list is documented in
45 the technical report. [39]

46 47 48 49 50 51 52 *Neighbourhood-level measures*

53
54 The neighbourhood was defined as the enumeration district (ED) a geographical unit consisting of
55 up to 400 dwellings. Home addresses were geographically linked to EDs within each parish using
56
57
58
59

1
2
3 ArcGIS 10.1 (ESRI, Redlands, CA, USA). A total of 113 EDs were analysed, with an average of
4 15 individuals per ED.
5

6 Interviewers' perceptions were aggregated for each subject/household and then to the ED
7 level to obtain markers at the neighbourhood level. An index of neighbourhood disorder was
8 created based on a composite score of the interviewers' perception of the condition of the homes,
9 condition of the streets, condition of the yards, the amount of noise, and the air quality in the
10 neighbourhoods. Scores for each variable ranged from 1 (excellent) to 4 (poor) and the overall
11 index ranged from 1 to 20, and therefore higher total scores indicated greater neighbourhood
12 disorder. While there are no gold standard measures for neighbourhood disorder, indices
13 representing both social and physical disorder in communities have been widely employed and
14 utilizing both self-reported or perceived as well as objective measures.[19, 54-56] Some have
15 included only markers of physical disorder, as is the case in the present study and a limitation;
16 however, physical disorder has been closely linked to social disorder but may not necessarily be a
17 marker of social disorder.[57-59] Nonetheless, physical disorder may contribute to biologic stress
18 markers such as CBR, irrespective of social disorder.
19

20 Recreational areas/playing fields/opens spaces availability in the participant's
21 neighbourhood was also assessed based on the interviewer's perception of a) the presence of and
22 b) walking distance to either recreational spaces, playing fields or other open spaces from a
23 participant's home. Scores assigned were 0 (no) and 1 (yes), with a total possible maximum score
24 of 2. Responses where an interviewer indicated an inability to assess or was unsure were excluded
25 from the analysis at the individual level. Eight percent of respondents were missing data on
26 neighbourhood-level items; however, those excluded did not differ in any way from those included
27 in the analysis. Both disorder and recreational availability were individual-level measures,
28 assessed based on the participant's home and immediate walking area around the home; therefore,
29 missing data was only at the level of the individual and not the ED.
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47

48 **Statistical analysis**

49 Data were analyzed descriptively using SAS complex survey design methods specifying weight,
50 stratum, and clustering variables to account for the JHLS sampling procedures when CBR was
51 described in terms of age and sex. Means and proportions were compared using survey-weighted
52 t-tests and the chi-squared test respectively. Two level multilevel models utilizing PROC MIXED
53
54
55
56
57
58
59

1
2
3 or PROC GLIMMIX for the dichotomized CBR were employed to examine clustering of CBR
4 across neighbourhoods and the impact of neighbourhood conditions on CBR. Multilevel models
5 were also weighted for sampling design and survey nonresponse and regression diagnostics for
6 linear models were conducted prior to the two-level multilevel modeling. We initially ran empty
7 models to determine group-level influences on individual outcomes, often expressed as the
8 Intraclass Correlation Coefficient (ICC) and calculated for our linear model as: $(V_{ED} / V_{ED} +$
9 $V_{individual}) \times 100$ where V_{ED} = variance between EDs and $V_{individual}$ = variance among individuals
10 within EDs. An ICC at or above 2% is suggestive of a potential higher level effect (e.g.,
11 neighbourhood) and worth examining in a multilevel framework. [60] Since the outcome variable
12 is binary, the ICC was calculated using Snijders formula where $V_{student} = \pi^2 / 3$. [61, 62]

13
14
15
16
17
18
19
20
21 Modeling was performed in the following steps: (1) examination of empty random
22 intercept models, in which there were no predictors, to determine the extent of clustering of CBR
23 values by neighbourhood, (2) testing the unadjusted associations between the neighbourhood
24 environments and CBR, (3) testing the adjusted association, after accounting for potential
25 confounders and testing potential interaction by sex, (4) test of random slope model, with
26 neighbourhood exposures considered as random effects, and (5) final stratified models, controlling
27 for potential confounders. Models were run with and without youth, as well as with and without
28 the unconventional asthma marker to test the stability of findings.

39 40 **Ethical Approval**

41 Ethical approval was received from the Ministry of Health, Jamaica and the University Hospital
42 of the West Indies.
43
44
45

46 47 **RESULTS**

48 The weighted sex and age stratified statistics are shown in Table 1. The mean age was
49 approximately 35 years for each sex and 73% of women had achieved at least high school level of
50 education compared to 69% for their male counterparts. Significant sex differences were noted
51 for all the individual cardiovascular and metabolic markers with the exception of FBG, with men
52 having greater SBP and DBP and women having higher WC and TC on average. Women had
53
54
55
56
57
58
59

1
2
3 significantly higher mean BMI (mean = 28.50 vs. 24.50, $p < 0.05$) and significantly higher mean
4 CBR scores than men (2.38 vs. 1.68, $p < 0.01$). No clustering was observed for the inflammatory
5 marker asthma. There were no sex differences in neighbourhood exposures, with similar
6 proportions of men and women having recreation or playing areas in their community and a similar
7 mean neighbourhood disorder score (Table 1). Youth comprised approximately 4% of the
8 participants. There were also significant age differences compared to adults for all the individual
9 cardiovascular and metabolic markers, including mean FBG.
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1. Weighted Descriptive Statistics and 95% CI by Sex: Jamaica Health and Lifestyle Survey 2008

Variable	Total (N= 2544)	Men (n=797)	Women(n=1747)	Youth (n=107)	Adults (n=2437)
Mean age (years)	35.23 (15.95-36.95)	34.89 (34.32-35.47)	35.37 (34.94-36.95)	16.09 (15.95-16.23)	36.60 (36.24-36.95)**
Education (%)					
< High school	28.43 (26.61-30.26)	31.44 (28.24-36.35)	27.16 (24.95-29.37)*	91.49 (86.38-96.61)	29.90 (27.99-31.81)**
≥ High school	71.56 (69.73-73.38)	68.55 (65.34-71.75)	72.84 (70.62-75.04)	8.51 (3.39-13.62)	70.09 (68.19-72.00)
Current smoker (%)	25.48 (23.72-27.24)	13.09 (11.96-14.23)	12.39 (10.96-13.89)	19.50 (10.78-28.17)	25.92 (24.15-27.69)*
Mean no. of possessions	9.34 (9.10-9.97)	9.69 (9.42-9.97)	9.19 (9.10-9.38)	9.26 (9.10-9.86)	9.28 (9.12-9.44)
Hypertension (%)	23.53 (22.01, 25.05)	22.88 (20.15, 25.61)	23.80 (21.97, 25.64)	4.67 (1.00, 8.36)	24.90 (23.30, 26.51)**
Diabetes (%)	7.44 (6.56, 8.31)	5.46 (4.15, 6.76)	8.28 (7.16, 9.40)**	0.76 (0.00, 2.27)	7.92 (6.99, 8.86)**
Mean SBP (mmHg)	121.53 (119.72-124.79)	123.75 (122.72-124.79)	120.57 (119.72-121.44)*	112.82 (110.28-115.42)	122.14 (121.43-122.86)**
Mean DBP (mmHg)	77.03 (75.84-79.19)	78.33 (77.47-79.19)	76.47 (75.84-77.11)*	70.49 (68.78-72.21)	77.49 (76.95-78.02)*
Mean WC (cm)	86.74 (86.13-87.35)	82.14 (81.27-83.00)	88.69 (87.92-89.48)*	74.77 (72.96-76.58)	87.61 (86.97-88.23)**
Mean TC (mg/dl)	4.40 (4.38-4.43)	4.25 (4.21-4.28)	4.47 (4.44-4.50)*	4.14 (4.06-4.21)	4.42 (4.39-4.45)*
Mean FBG (mM/L)	4.10 (4.02-4.18)	4.12 (3.97-4.28)	4.09 (4.01-4.18)	3.47 (3.29-3.66)	4.15 (4.07-4.23)*
Mean BMI	27.25 (26.99-27.52)	24.50 (24.09-24.87)	28.50 (28.10-28.80)*	23.19 (22.23-24.13)	27.54 (27.27-28.81)**
Self-reported asthma (%)	7.42 (3.82-9.54)	5.52 (3.82-7.17)	8.23 (6.93-9.54)	8.01 (4.72-8.46)	7.24 (6.18-8.29)
Mean CBR score	2.18 (2.12-2.24)	1.68 (1.58-1.79)	2.38 (2.31-2.46)**	1.06 (0.84-1.26)	2.26 (2.19-2.32)**
Mean Neighbourhood Disorder score †	11.71 (11.52-11.89)	11.35 (11.04-11.66)	11.85 (11.62-12.08)	12.33 (11.58-13.07)	11.66 (11.47-11.85)
Recreational Space Availability (%) †	59.04 (56.89-61.79)	59.67 (55.18-64.14)	58.78 (55.35-62.20)	55.56 (44.09-66.99)	59.28 (56.50-62.06)

* $p < 0.05$ and ** $p < 0.01$, for comparisons between men and women and between youth and adults. Youth defined as < 18 years.

† Based on the participant's enumeration district (ED), with a total of 113 EDs in the study.

Abbreviations: 95% CI - 95% confidence interval; SBP - Systolic Blood Pressure; DBP- Diastolic Blood Pressure; WC - Waist Circumference; TC - Total Cholesterol; FBG - Fasting Blood Glucose; BMI - Body Mass Index; CBR - Cumulative Biological Risk

Neighbourhood Disorder Score: This comprises a composite score of the interviewers' perception of the condition of homes, streets and yards, amount of noise and air quality of neighbourhoods. Scores for each variable ranged from 1 (excellent) to 4 (poor) and the overall index from 1 to 20, with a higher score indicating greater neighbourhood disorder.

Recreational Space Availability: This was based on the interviewer's perception of a) the presence of and b) walking distance to either recreational spaces, playing fields or other open spaces from a participant's home. Scores assigned were 0 (no) and 1 (yes), with a total possible maximum score of 2.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Twenty-two percent of the sample was considered to have high CBR. Figure 1 presents the total and sex-specific percentages of high CBR scores in 10-year age groups. The 35-44-year-old group had the largest percentage (31%) of high CBR scores with an approximate 20% difference in high scores between women and men. Sex differences in mean scores tapered off in older and younger age groups but remained significant at all ages.

We observed significant clustering of CBR at the neighbourhood level with an ICC of 4.6% (Figure 2). This suggests that some of the variance observed in CBR may be explained by neighbourhood level factors. Significant clustering with ICC values of over 4.0% was observed for all other biomarkers except for self-reported asthma and FBG. The highest levels of clustering were seen for both DBP and SBP. Also shown in Figure 2 are ICCs by sex and demonstrates the substantial difference in clustering by ED between women and men (6.9% vs. 0.7%).

Neighbourhood characteristics and CBR

Table 2 presents combined and sex-specific results from the multilevel logistic regression models utilizing CBR as a dichotomous outcome. For the combined results (adjusted for age, sex and number of possessions) the likelihood of high CBR was significantly lower among respondents with greater recreational space availability (aOR = 0.75; 95% CI = 0.64, 0.94; $p < 0.05$). Controlling for the other individual level covariates such as smoking, diet or physical activity did not alter the associations and were therefore not included in models. While the overall association between neighbourhood disorder and high CBR was not statistically significant, significant interaction by sex was observed. Sex-specific results revealed a significant association between neighbourhood disorder score and high CBR (OR = 1.26; 95% CI = 1.08, 1.47; $p < 0.05$) in women but not for men (OR = 0.97; 95% CI = 0.86, 1.09), with the likelihood of high CBR increasing by 26% for each unit increase in neighbourhood disorder score among women. Results were consistent when using CBR as a continuous variable.

Table 2. Unadjusted and adjusted Odds Ratio (95% CI) for High CBR[†] Overall and Stratified by Sex (N=2,544)

Neighbourhood Characteristic	Overall CBR (95%CI)		CBR Stratified by Sex (95%CI)	
	Unadjusted	Adjusted ^{††}	Women	Men
Neighbourhood Disorder Score	1.00 (0.97-1.03)	1.01 (0.98-1.04)	1.26 (1.08-1.47)*	0.97 (0.86-1.09)
ICC (%)	3.10	2.46	2.83	2.20
Recreational Space Availability	0.79 (0.65-0.95)*	0.75 (0.64-0.90)*	0.82 (0.49-1.36)	0.91 (0.63-1.29)
ICC (%)	3.20	2.54	4.80	2.09

CBR - Cumulative Biological Risk; ICC – Intraclass Correlation Coefficient. ICC was calculated as $(V_{ED} / (V_{ED} + V_{individual})) \times 100$ where V_{ED} = variance between EDs and $V_{individual}$ = variance among individuals within EDs.

[†] High CBR was defined as at least one standard deviation above the mean score.

^{††} Adjusted for age, sex, education, no. of possessions, smoking status; stratified by sex, adjusted for age, education and no. of possessions.

* $p < 0.05$

We observed no statistically significant interaction by sex in the relationship between recreational space availability and high CBR. Inclusion of both neighbourhood exposures and individual level covariates did reduce the ICC overall. All analyses were also run with and without youth included, as well as with and without the unconventional asthma marker and there were no changes in the overall results.

DISCUSSION

CBR increased with age for both sexes and was significantly higher among women. Higher levels of recreational space availability were associated with less CBR and greater neighbourhood disorder was significantly associated with high CBR for women but not men.

Our findings are consistent with reports elsewhere of an increase in CBR with age, at least up to the 6th decade of life. [4, 24, 63] In our study, CBR increased with age for both sexes, and was consistently higher among the women across the lifespan. This is consistent with studies that have found this sex differential, [25, 64] but is a novel contribution to the existing literature given that our study population included women from as young as 15 years old, while the majority of studies examining sex differences in CBR include only older adult women. We are unclear if this sex differential reflects genetic and/or gender underpinnings unique to the Jamaican context, or simply differences with unmeasured sample characteristics. Additionally, while our findings align with literature on poorer women's susceptibility to repeated exposures and adaptations to stressors

1
2
3 in more developed country contexts, [4] the scholarship on CBR in developing contexts such as
4 the Caribbean is limited. Studies in Jamaica have documented a strong association between
5 morning salivary cortisol levels and hypertension, [65] in mothers and their offspring. Future
6 studies examining sex differences in the association between cortisol and other specific
7 neuroendocrine and immune/inflammatory indicators used in the operationalization of CBR may
8 explain this observed sex differential. We were unable to assess racial disparities given that
9 Jamaicans are predominantly Black. However, studies in the USA have found that Black women
10 exhibit greater CBR than Black men and more so than other racial groups. [4, 10] This suggests
11 possible epigenetic and/or environmental underpinnings. Our analysis had no neuroendocrine
12 markers, and some are recognized to produce differentially higher response to stress in Blacks.
13 [66]

14
15 The clustering of CBR across neighbourhoods indicates that some of the variance in CBR
16 may be due to neighbourhood environment, and more so for women.[45] Findings corroborate
17 those that have reported the stress reducing effects of recreational spaces,[67] others that have
18 demonstrated an effect of neighbourhood stress on CBR,[19, 20] and add to the work examining
19 the differential impact of such contextual stress by sex. Research has shown that women
20 subjectively experience more stress than men and consistently report more physical and
21 somatoform symptoms and show higher stress vulnerability. [31-34] Availability of physical
22 activity spaces in neighbourhoods has been associated with better cardiovascular and mental
23 health. [68, 69] The lack of community spaces for physical activity may be a barrier to engaging
24 in physical activity for residents. Neighbourhood disorder may be a marker of more deprived
25 community environments, whereby healthy food access is limited [70, 71] and may lead to higher
26 CBR. [25] Disorder and the stress it may induce could also lead to differences in coping,
27 particularly among women. Fernandez et al, [72] found that the disengagement coping styles of
28 African American women - when a person avoids a stressor (e.g., “I try not to think about the
29 problem”), measured by using the Coping Strategies Inventory Short Form, were associated with
30 significantly higher CBR levels. Disorder may also be related to physical activity. Our disorder
31 marker included condition of the streets, which may impact even utilitarian physical activity [73,
32 74] and thereby CBR levels. Furthermore, our marker of neighbourhood disorder included air
33 quality, which may also directly impact CBR, through the immune/inflammatory system. [75]
34 However, our literature review has not revealed evidence supporting greater exposure of women
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 versus men to poorer air quality in residential environments. Future behavioural studies exploring
4 similar associations may help identify additional covariates which can inform sex-specific
5 interventions for reducing CBR among Jamaicans. Our finding that greater neighbourhood
6 disorder was significantly associated with high CBR for women but not men may reflect
7 neighbourhood disorder serving as a proxy for neighbourhood SES.[45] While this finding aligns
8 with a few others on poorer women's susceptibility to repeated exposures and adaptations to
9 stressors in more developed country contexts,[4, 13, 76] similar scholarship on CBR in developing
10 contexts such as the Caribbean is limited.

11
12
13
14
15
16
17 There are strengths and potential limitations of this study. Strengths include the fact that
18 this is the first study to demonstrate sex differences in CBR in a small island developing country,
19 and the first to examine neighbourhood influences including factors beyond socioeconomic status,
20 on biologic stress in a middle-income country context. In addition, this study provided a large
21 sample size representative of Jamaicans 15 to 74 years. Utilization of a multilevel approach and
22 examination of cumulative biologic risk in this context is another strength. On the other hand, there
23 are a number of potential limitations. Firstly, cross-sectional data were used which limits our
24 ability to make inferences regarding causation or say definitively whether our findings show age
25 trends. It also may not be possible to generalize our results to other Black populations. Secondly,
26 we are also unclear if the observed sex differential reflects genetic, environmental and/or gender
27 underpinnings unique to the Jamaican context, or simply differences with unmeasured sample
28 characteristics. For example, our results suggest an independent effect for cumulative biological
29 risk neighbourhood disorder-level context in women, but not for men. However, the analysis
30 lacked sex specific individual level data such as sex-specific exposure and physiological and/or
31 neuro-hormonal changes. Individual-level socioeconomic status effects could be more apparent
32 than aggregate neighbourhood disorders or at the very least that they would provide independent
33 or confounded impacts for cumulative biological risk. Additionally, there is no agreed gold
34 standard for the operationalisation of CBR or AL. For example, our study included only 7 markers
35 compared with others that used between 9 and 11 biomarkers. [7, 76] In particular, as stated
36 previously we had no individual-level neuroendocrine or immune biomarkers and may have
37 missed other important associations. Of note, studies in Jamaica have documented a strong
38 association between morning salivary cortisol levels and hypertension in mothers and their
39 offspring. [62] Additionally, the neighbourhood was defined as an ED, many of which are
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 heterogeneous. It is quite possible that important geographic effects may have been misclassified
4 or not captured. Neighbourhood characteristics were subjectively assessed by interviewers,
5 increasing the possibility of information bias. We also had no information on the interrater
6 reliability of neighborhood assessments, given the existing nature of the data and timeframe since
7 data collection. While we assume, given the information on training of interviewer perceptions,
8 that the reliability was high, there was no way to test this.
9

10
11 Targeting neighbourhood change is feasible and may not only improve neighbourhood
12 quality but also exert a small, sustained improvement in the health of women in those
13 neighbourhoods. From a public health perspective, such structural changes offer an effective
14 alternative method for reducing health disparities. In Jamaica we have found significant clustering
15 at the neighbourhood level in obesity and significant increase in obesity among women in the
16 absence of supermarkets and markets, suggesting the need for greater emphasis on policies,
17 programmes and interventions that are focused on the neighbourhood-level effects.[77] This study
18 delves even deeper, considering potential biologic impacts that may occur irrespective of women's
19 individual behaviours, and suggests policymakers and clinicians implement programmes focusing
20 on earlier monitoring of biologic stress before NCDs develops.
21

22
23 The results from this study also strengthen the case for multidisciplinary local and
24 regional health research that is sensitive to sex differences in exposures and vulnerabilities that
25 likely contribute to CBR differences and related health outcomes such as NCDs. The higher CBR
26 score among women in tandem with the higher ICC levels for the women versus men by EDs,
27 suggests that gender specific factors must be considered in the development of a programme of
28 research on CBR in the Jamaican health context.[45] The sex differences in CBR clustering by
29 ED also suggests the need for multilevel models that address the possible gendered vulnerabilities
30 and exposures within the context of objective measurements of neighbourhood disorder and other
31 neighbourhood level factors.
32

33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 **STATEMENTS** 49

50
51 **Contributors** CCM, IG and KT conceived the study. LG and PLA geocoded the data. CCM, EM,
52 KT, and NYC analysed the data. CCM wrote the manuscript. MTR, SM, DF, GGS, RW and KT
53 edited the paper. All authors approved the final manuscript.
54
55
56
57
58
59

1
2
3
4
5 **Funding** The JHLS II was supported by the National Health Fund, Jamaica.
6
7

8 **Competing interests** None declared
9

10
11 **Ethics approval** The JHLS II was approved by the Ministry of Health, Jamaica and the University
12 Hospital of the West Indies. No additional ethical approval was necessary for this secondary data
13 analysis.
14
15
16

17
18 **Provenance and peer review** Not commissioned; externally peer reviewed.
19
20

21 **Data sharing statement** No additional data are available.
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

REFERENCES

1. Beaglehole R, Bonita R, Horton R, *et al.* Priority actions for the non-communicable disease crisis. *Lancet* 2011; 377(9775):1438-1447.
2. McEwen BS, Stellar E. Stress and the individual: mechanisms leading to disease. *Arch Intern Med* 1993; 153(18):2093.
3. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med* 1998; 338(3):171.
4. Geronimus AT, Hicken M, Keene D, *et al.* "Weathering" and age patterns of allostatic load scores among blacks and whites in the United States. *Am J Public Health* 2006; 96(5):826-33.
5. Borrell LN, Dallo FJ, Nguyen N. Racial/ethnic disparities in all-cause mortality in US adults: the effect of allostatic load. *Public Health Rep* 2010; 125(6):810.
6. Seeman TE, Singer BH, Rowe JW, *et al.* Price of adaptation--allostatic load and its health consequences. MacArthur studies of successful aging. *Arch Intern Med* 1997; 157(19):2259-68.
7. Beckie TM. A Systematic Review of Allostatic Load, Health, and Health Disparities. *Biol Res Nurs* 2012;14(4):311-346.
8. McEwen B, Seeman T. Protective and damaging effects of mediators of stress: elaborating and testing the concepts of allostasis and allostatic load. *Ann N Y Acad Sci* 1999; 896(1):30-47.
9. Seeman TE, McEwen BS. Social environment characteristics and neuroendocrine function: the impact of social ties and support on neuroendocrine regulation. *Psychosom Med* 1996;58(5):459-71
10. Bird CE, Seeman T, Escarce JJ *et al.* Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *J Epidemiol Community Health* 2010; 64(10):860-5.
11. King KE, Morenoff JD, House JS. Neighborhood context and social disparities in cumulative biological risk factors. *Psychosom Med* 2011;73(7):572-579.
12. Schulz AJ, Mentz G, Lachance L, *et al.* Associations between socioeconomic status and allostatic load: effects of neighborhood poverty and tests of mediating pathways. *Am J Public Health* 2012;102(9):1706-1714.

13. Merkin S, Basurto-Dávila R, Karlamangla A, *et al.* Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of US adults: NHANES III. *Ann Epidemiol* 2009;19(3):194.
14. Robinson AI, Carnes F, Oreskovic NM. Spatial analysis of crime incidence and adolescent physical activity. *Prev Med* 2016; 85:74-7.
15. Sallis JF, Bowles HR, Bauman A, *et al.* Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med* 2009;36(6):484-90.
16. Swinburn BG, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 1999;29(6 Pt 1):563-70.
17. Gordon-Larsen P, Nelson MC, Page P, *et al.* Inequality in the built environment underlies key health disparities in physical activity and obesity. *Pediatrics* 2006;117(2):417-24.
18. Ross C, Mirowsky J. Neighborhood disadvantage, disorder, and health. *J Health Soc Behav* 2001;43(2):258-276.
19. Theall KP, Brett ZH, Shirtcliff EA, *et al.* Neighborhood disorder and telomeres: connecting children's exposure to community level stress and cellular response. *Soc Sci Med* 2013; 85:50-8.
20. Hosseini F, Adha N, Zainol R, *et al.* Neighborhood-Level Stress and Circadian Cortisol: A Systematic Review and Meta-Analysis. *Iran J Public Health* 2014;43(10):1324-34.
21. Stafford M, Cummins S, Ellaway A, *et al.* Pathways to obesity: identifying local, modifiable determinants of physical activity and diet. *Soc Sci Med* 2007; 65(9):1882-1897.
22. Harrington DW, Elliott SJ. Weighing the importance of neighbourhood: a multilevel exploration of the determinants of overweight and obesity. *Soc Sci Med* 2009;68(4):593-600.
23. Diez Roux AV, Mujahid MS, Hirsch JA, *et al.* The impact of neighborhoods on CV risk. *Glob Heart* 2016;11(3): 353-363.
24. Yang Y, Kozloski M. Sex differences in age trajectories of physiological dysregulation: inflammation, metabolic syndrome, and allostatic load. *J Gerontol A Biol Sci Med Sci* 2011;66(5):493-500.
25. Kusano Y, Crews DE, Iwamoto A, *et al.* Allostatic load differs by sex and diet, but not age in older Japanese from the Goto Islands. *Ann Hum Biol* 2015:1-8.

- 1
 - 2
 - 3
 - 4
 - 5
 - 6
 - 7
 - 8
 - 9
 - 10
 - 11
 - 12
 - 13
 - 14
 - 15
 - 16
 - 17
 - 18
 - 19
 - 20
 - 21
 - 22
 - 23
 - 24
 - 25
 - 26
 - 27
 - 28
 - 29
 - 30
 - 31
 - 32
 - 33
 - 34
 - 35
 - 36
 - 37
 - 38
 - 39
 - 40
 - 41
 - 42
 - 43
 - 44
 - 45
 - 46
 - 47
 - 48
 - 49
 - 50
 - 51
 - 52
 - 53
 - 54
 - 55
 - 56
 - 57
 - 58
 - 59
 - 60
26. Juster R.-P, Lupien S. A sex-and gender-based analysis of allostatic load and physical complaints. *Gen Med* 2012;9(6):511-523.
27. Lloyd-Jones DM, Wilson PWF, Larson MG, *et al.* Framingham risk score and prediction of lifetime risk for coronary heart disease. *Am J Cardiol* 2004;94(1):20-24.
28. Eskes T, Haanen C. Why do women live longer than men? *Eur J Obstet Gynecol Reprod Biol* 2007;133(2):126-133.
29. Schuurs AHW, Verheul HAM. Effects of gender and sex steroids on the immune response. *J Steroid Biochem* 1990;35(2):157-172.
30. Stafford M, Cummins S, Macintyre S, *et al.* Gender differences in the associations between health and neighbourhood environment. *Soc Sci Med* 2005;60(8):1681-92.
31. Barnett R, Biener L, Baruch G. Gender and stress. The Free Press, 1987.
32. Bebbington P, Dunn G, Jenkins R, *et al.* The influence of age and sex on the prevalence of depressive conditions: report from the National Survey of Psychiatric Morbidity. *Int Rev Psychiatry* 2003;15(1-2):74-83.
33. Kessler R, Brown R, Broman C. Sex differences in psychiatric help-seeking: Evidence from four large-scale surveys. *J Health Soc Behav* 1981:49-64.
34. Kessler R, McLeod J. Sex differences in vulnerability to undesirable life events. *Am Sociol Rev* 1984:620-631.
35. LaVeist TA, Wallace JM, Jr. Health risk and inequitable distribution of liquor stores in African American neighborhood. *Soc Sci Med* 2000;51(4):613-7.
36. Lean M, Han T, Morrison C. Waist circumference as a measure for indicating need for weight management. *BMJ* 1995;311(6998):158.
37. Theall KP, Drury SS, Shirtcliff EA. Cumulative Neighborhood Risk of Psychosocial Stress and Allostatic Load in Adolescents. *Am J Epidemiol* 2011;176(suppl 7): S164-S174.
38. Chum A, O'Campo P. Cross-sectional associations between residential environmental exposures and cardiovascular diseases. *BMC Public Health*, 2015;15(1):438.
39. Wilks R, Younger N, Tulloch-Reid M, *et al.* Jamaica Health and Lifestyle Survey 2007-8. Available from: http://www.mona.uwi.edu/reports/health/JHLSII_final_may09.pdf.
40. Abdulkadri AO, Cunningham-Myrie C, Forrester T. Economic burden of diabetes and hypertension in CARICOM states. *Soc Econ Stud* 2009;58 (3 &4):175-197.

- 1
2
3 41. Hospedales CJ, Samuels T, Cummings R, *et al.* Raising the priority of chronic
4 noncommunicable diseases in the Caribbean. *Rev Panam Salud Pública* 2011;30(4):393-
5 400.
6
7
- 8 42. Statistical Institute of Jamaica 2015. Available from:
9 http://statinja.gov.jm/living_conditions_poverty.aspx. (accessed June 15, 2018)
10
- 11 43. Austin-Broos, D. Urban life in Kingston Jamaica: the culture and class ideology of two
12 neighborhoods. Routledge, 2017.
13
- 14 44. Lowe GA, Lipps G, Gibson RC, *et al.* Neighbourhood factors and depression among
15 adolescents in four Caribbean countries. *PloS One* 2014; 9(4):e95538.
16
- 17 45. Mullings JA, McCaw-Binns AM, Archer C, *et al.* Gender differences in the effects of urban
18 neighborhood on depressive symptoms in Jamaica. *Rev Panam Salud Pública* 2013;34(6):
19 385-92.
20
- 21 46. Cunningham-Myrie CA, Theall KP, Younger NO, *et al.* Associations between
22 neighborhood effects and physical activity, obesity, and diabetes: The Jamaica Health and
23 Lifestyle Survey 2008. *J Clin Epidemiol* 2015;68(9):970-8.
24
- 25 47. Bernard P, Charafeddine R, Frohlich KL, *et al.* Health inequalities and place: a theoretical
26 conception of neighbourhood. *Soc Sci Med* 2007;65(9):1839-1852.
27
- 28 48. Sampson R, Morenoff J. Spatial (Dis)Advantage and Homicide in Chicago
29 Neighborhoods, in Spatially Integrated Social Science, M. Goodchild and D. Janelle,
30 Editors. 2004, Oxford: New York, NY. 145-170.
31
- 32 49. Krieger N. Methods for the scientific study of discrimination and health: an ecosocial
33 approach. *Am J Public Health* 2012;102(5):936-944.
34
- 35 50. Barnes PJ. Immunology of asthma and chronic obstructive pulmonary disease. *Nat Rev*
36 *Immunol* 2008;8(3):183-92.
37
- 38 51. Roth GA, Fihn SD, Mokdad AH, *et al.* High total serum cholesterol, medication coverage
39 and therapeutic control: an analysis of national health examination survey data from eight
40 countries. *Bull World Health Organ* 2011;89(2):92-101.
41
- 42 52. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate
43 hyperglycaemia: report of a WHO/IDF Consultation Report. 2006.
44
- 45 53. Koebnick C, Black MH, Wu J, *et al.*, High blood pressure in overweight and obese youth:
46 implications for screening. *J Clin Hyperens (Greenwich)* 2013;15(11):793-805.
47
48
49
50
51
52
53
54
55
56
57
58
59
60

- 1
- 2
- 3
- 4 54. Sampson RJ, Raudenbush SW. Systematic social observation of public spaces: A new look
- 5 at disorder in urban neighborhoods. *Am J Sociol* 1999; 105(3):603-651.
- 6
- 7 55. Odgers CL, Caspi A, Bates CJ, *et al.* Systematic social observation of children's
- 8 neighborhoods using Google Street View: a reliable and cost-effective method. *J Child*
- 9 *Psychol Psychiatry* 2012;53(10):1009-1017.
- 10
- 11 56. Ross CE, Jang SJ. Neighborhood disorder, fear, and mistrust: The buffering role of social
- 12 ties with neighbors. *Am J Community Psychol* 2000;28(4):401-420.
- 13
- 14 57. Sampson RJ, Raudenbush SW. "Seeing disorder: Neighborhood stigma and the social
- 15 construction of "broken windows". *Soc Psychol Q* 2004;67(4):319-342.
- 16
- 17 58. Duneier M. *Sidewalk*. Macmillan, 1999.
- 18
- 19 59. Harcourt BE. *Illusion of order: The false promise of broken windows policing*. Harvard
- 20 University Press, 2009.
- 21
- 22 60. Raudenbush SW, Bryk AS. *Hierarchical linear models: Applications and data analysis*
- 23 *methods*. Sage Publications, Incorporated Vol. 1, 2001.
- 24
- 25 61. Snijders TAB, Bosker RJ. *Multilevel analysis: an introduction to basic and advanced*
- 26 *multilevel modeling*. Thousand Oaks, Calif. ; London: SAGE, 1999.
- 27
- 28 62. Merlo J, Chaix B, Ohlsson H, *et al.* A brief conceptual tutorial of multilevel analysis in
- 29 social epidemiology: using measures of clustering in multilevel logistic regression to
- 30 investigate contextual phenomena. *J Epidemiol Community Health* 2006;60(4):290-7.
- 31
- 32 63. Crimmins EM, Johnston M, Hayward M, *et al.* Age differences in allostatic load: an index
- 33 of physiological dysregulation. *Exp Gerontol* 2003;38(7):731-734.
- 34
- 35 64. Mair CA, Cutchin MP, Peek MK. Allostatic load in an environmental riskscape: The role
- 36 of stressors and gender. *Health Place* 2011;17(4):978-987.
- 37
- 38 65. Boyne MS, Woolard A, Phillips DI, *et al.* The association of hypothalamic-pituitary-
- 39 adrenal axis activity and blood pressure in an Afro-Caribbean population.
- 40 *Psychoneuroendocrinology* 2009;34(5):736-42.
- 41
- 42 66. Chong RY, Uhart M, McCaul ME, *et al.* Whites have a more robust hypothalamic-
- 43 pituitary-adrenal axis response to a psychological stressor than blacks.
- 44 *Psychoneuroendocrinology* 2008;33(2):246-54.
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
67. Stigsdotter UK, Ekholm O, Schipperijn J, *et al.* Health promoting outdoor environments--associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scand J Public Health* 2010;38(4):411-7.
 68. Richardson EA, Pearce J, Mitchell R, *et al.* Role of physical activity in the relationship between urban green space and health. *Public Health* 2013;127(4):318-324
 69. Ord K, Mitchell R, Pearce J. Is level of neighbourhood green space associated with physical activity in green space? *Int J Behav Nutr Phys Act* 2013;10(1):127
 70. Bower KM, Thorpe RJ, Jr., Rohde C, *et al.* The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Prev Med* 2014;58:33-9.
 71. Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the location and type of food stores. *Am J Public Health* 2006;96(2): 325-331.
 72. Fernandez CA, Loucks EB, Arheart KL, *et al.* Evaluating the Effects of Coping Style on Allostatic Load, by Sex: The Jackson Heart Study, 2000-2004. *Prev Chronic Dis* 2015;12:E165.
 73. Lee C, Ory MG, Yoon J, *et al.* Neighborhood walking among overweight and obese adults: age variations in barriers and motivators. *J Community Health* 2013;38(1):12-22.
 74. Miles R, Panton LB, Jang M, *et al.* Residential context, walking and obesity: two African-American neighborhoods compared. *Health Place* 2008;14(2):275-86.
 75. Clougherty JE, Kubzansky LD. A framework for examining social stress and susceptibility to air pollution in respiratory health. *Environ Health Perspect* 2009;117(9): 1351-8.
 76. Hickson DA, Diez Roux AV, Gebreab SY, *et al.* Social Patterning of Cumulative Biological Risk by Education and Income Among African Americans. *Am J Public Health* 2012;102(7):1362-1369.
 77. Myrie CA. An Exploration of Geographic Variation in Obesity, Its Key Risk Factors and Comorbidities. Are There Opportunities for Tailoring Public Health Interventions? Secondary Analysis of The Jamaica Health and Lifestyle Survey 2008 (JHLS II) [dissertation]. Mona, Jamaica; University of the West Indies; 2018. 371 p.

Figure 1 Proportion High CBR[†] score by age and sex

CBR – Cumulative Biological Risk

[†]High CBR was defined as at least one standard deviation above the mean score.

*p < 0.01 and **p < 0.0001 comparing sex differences within each age group

For peer review only

1
2
3 **Figure 2** Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High
4 Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.
5

6 CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure;
7 WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body
8 Mass Index* High CBR was defined as at least one standard deviation above the mean score.

9 ** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma, DBP
10 > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and BMI
11 \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation above
12 the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and DBP,
13 with high risk cut-points defined as being greater than or equal to the 94th percentile for age, sex,
14 and BMI.
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

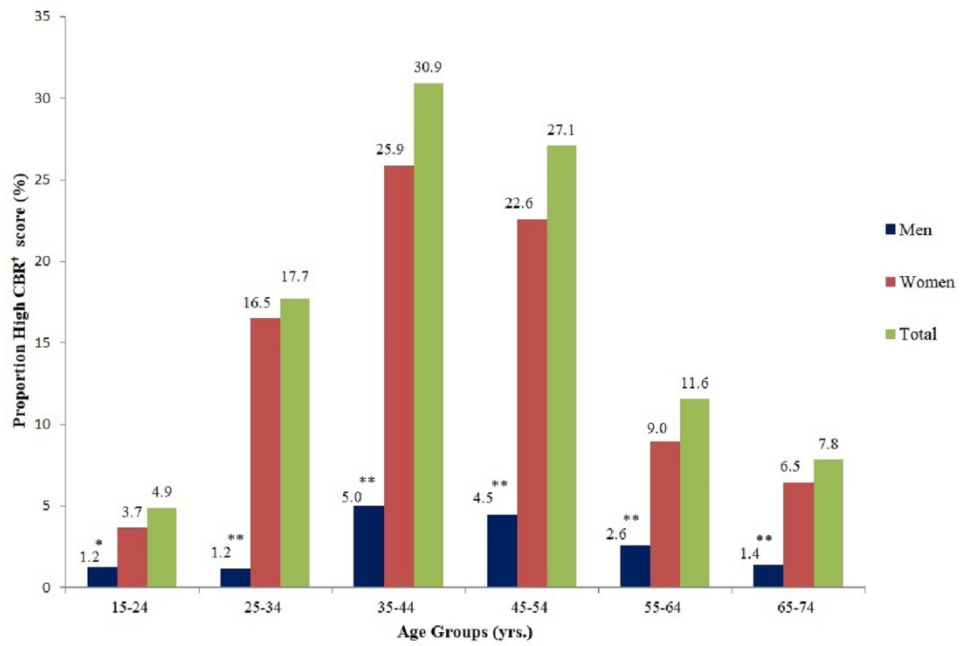


Figure 1. Proportion High CBR score by age and sex. CBR, Cumulative Biological Risk; †High CBR was defined as at least one standard deviation above the mean score. *P < 0.01; **P < 0.0001

140x93mm (300 x 300 DPI)

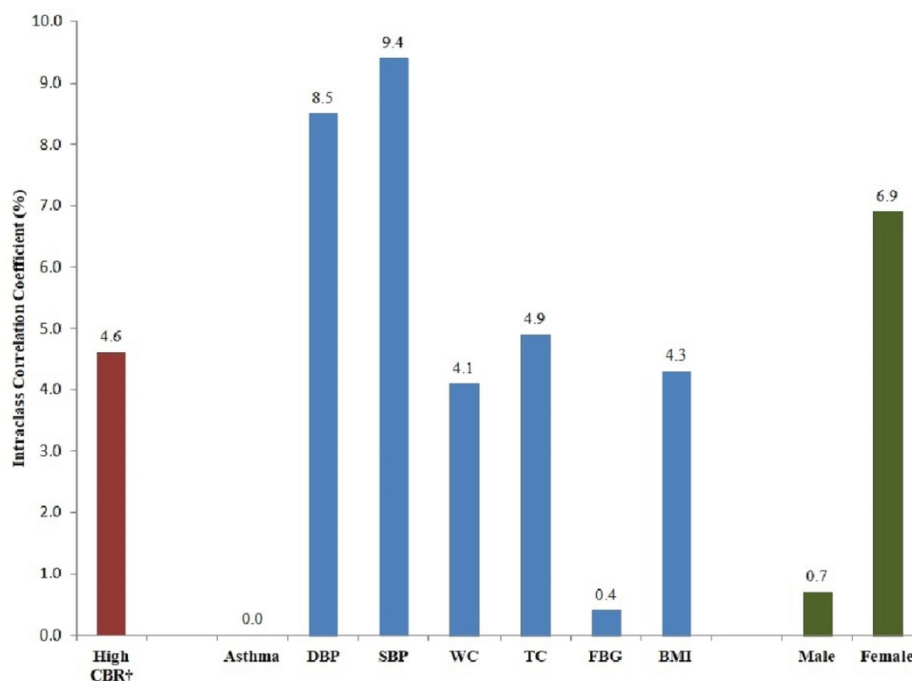


Figure 2. Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.

CBR, Cumulative Biologic Risk; DBP, Diastolic Blood Pressure; SBP, Systolic Blood Pressure; WC, Waist Circumference; TC, Total Cholesterol; FBG, Fasting Blood Glucose; BMI, Body Mass Index* High CBR was defined as at least one standard deviation above the mean score.

** Individual biomarkers were included based on high risk cut-points: Self-reported Asthma, DBP > 85 mmHg, SBP > 130 mmHg, WC > 85 mmHg, TC > 5.7 mM/L, FBG \geq 110 mg/dL and BMI \geq 25 kg/m²; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or \geq the adult high risk cut-point value, except for SBP and DBP, with high risk cut-points defined as being greater than or equal to the 94th percentile for age, sex, and BMI.

131x90mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study’s design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-9
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-9
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	8-9
		(b) Describe any methods used to examine subgroups and interactions	8-9
		(c) Explain how missing data were addressed	6-8
		(d) If applicable, describe analytical methods taking account of sampling strategy	8
		(e) Describe any sensitivity analyses	9
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6-8
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	10
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12
		(b) Report category boundaries when continuous variables were categorized	7
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	16

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.