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

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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 then 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

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

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

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

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 ≥ 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

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

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

Ethical Approval

Ethical approval was received from the Ministry of Health, Jamaica and the University Hospital of the West Indies.

RESULTS

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

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

Twenty-two percent of the sample were considered to have high CBR. Figure 2 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 3). 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 3 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. 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

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

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

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

There are potential limitations of this study. 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 neighborhood 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 neighborhood 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 59] 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.[49] 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 21] It is possible medication use may have decreased CBR due to a shift of biomarkers below the high risk cut points or increased it among the young, for whom taking medication would indicate that some systemic dysregulation has already occurred.[4] Additionally, the neighbourhood was defined as an ED, many of which are heterogeneous. It is quite 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. We also had no information on the interrater reliability of neighborhood assessments, given the existing nature of the data and timeframe since data collection. While we assume, given the information on training of interviewer perceptions, that the reliability was high, there was no way to test this. Finally, we have no data on lifetime history or risk factors (e.g. trauma or abuse, childhood socioeconomic status, birthweight or childhood nutrition) that may also impact CBR in adulthood.

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

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

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.

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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.

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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]

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

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 ≥ 110 mg/dL and BMI ≥ 25 kg/m^2; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or ≥ 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.

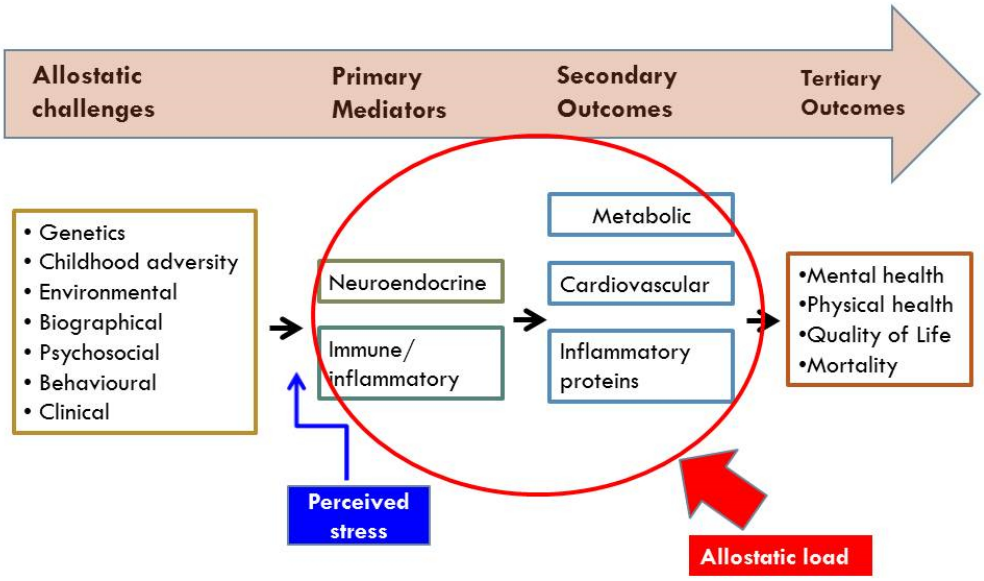


Figure 1 Heuristic model: Allostatic load, health and health disparitiesAdapted from Beckie TM. A Systematic Review of Allostatic Load, Health, and Health Disparities.[7]

254x190mm (96 x 96 DPI)

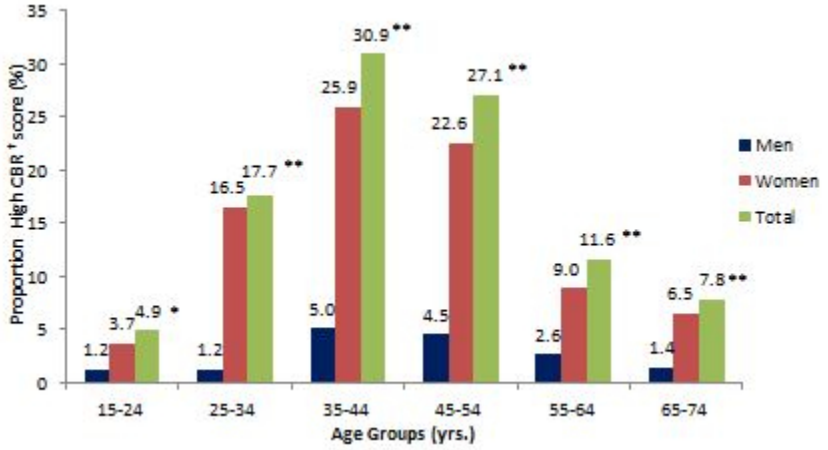
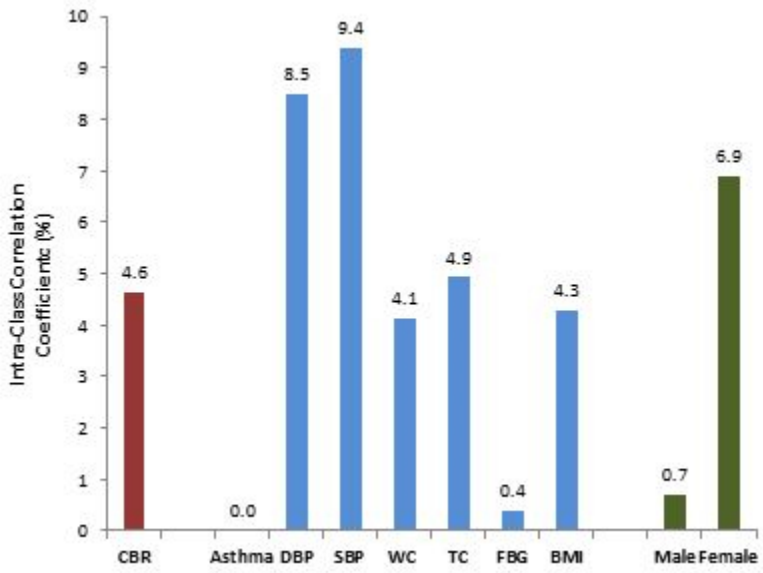


Figure 2 Proportion High CBR† score by age and sexCBR – Cumulative Biological Risk †High CBR was defined as at least one standard deviation above the mean score. *p < 0.01,**p < 0.0001

111x61mm (96 x 96 DPI)



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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.

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

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

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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 then 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

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

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

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

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

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

Through a secondary analysis of the JHLS II dataset, we examine the relation between neighbourhood conditions—specifically, neighbourhood disorder and availability of recreational spaces—and CBR in Jamaica, as well as differences by sex. We hypothesized 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.[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

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.[50] It has been used in previous studies assessing CBR.[37]

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,[36] ≥ 25 kg/m2 for BMI, > 6.2 mM/L for TC levels [51] and ≥ 110 mg/dL (6.1mmol/L) for FBG levels.[52] CBR was examined as both a continuous and a dichotomous variable. 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 (self-reported asthma included). 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.[53]

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

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). Household crowding was also examined as a potential confounder, defined as both more than one person per habitable room as well as the average number of individuals per habitable room. A complete list is documented in the technical report.[39]

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.

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, and therefore higher total scores indicated greater neighbourhood disorder. While there are no gold standard measures for neighbourhood disorder, indices representing both social and physical disorder in communities have been widely employed and utilizing both self-reported or perceived as well as objective measures.[19, 54-56] Some have included only markers of physical disorder, as is the case in the present study and a limitation; however, physical disorder has been closely linked to social disorder but may not necessarily be a marker of social disorder.[57-59] Nonetheless, physical disorder may contribute to biologic stress markers such as CBR, irrespective of social disorder.

Recreational areas/playing fields/opens spaces availability in the participant's neighbourhood was also assessed 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. Responses where an interviewer indicated an inability to assess or was unsure were excluded from the analysis at the individual level. Eight percent of respondents were missing data on neighbourhood-level items; however, those excluded did not differ in any way from those included in the analysis. Both disorder and recreational availability were individual-level measures, assessed based on the participant's home and immediate walking area around the home; therefore, missing data was only at the level of the individual and not the ED.

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: $(V_{ED} / V_{ED} + V_{individual}) X 100$ 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 framework.[60] Since the outcome variable is binary, the ICC was calculated using Snijders formula where $V_{student} = \prod 2 / 3$.[61, 62]

Modeling was performed in the following steps: (1) examination of empty random intercept models, in which there were no predictors, to determine the extent of clustering of CBR values by neighbourhood, (2) testing the unadjusted associations between the neighbourhood environments and CBR, (3) testing the adjusted association, after accounting for potential confounders and testing potential interaction by sex, (4) test of random slope model, with neighborhood exposures considered as random effects, and (5) final stratified

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

Ethical Approval

Ethical approval was received from the Ministry of Health, Jamaica and the University Hospital of the West Indies.

RESULTS

The weighted sex and age stratified statistics are shown in Table 1. The mean age was approximately 35 years for each sex and 73% of women had achieved at least high school level of education compared to 69% for their male counterparts. Significant sex differences were noted for all the individual cardiovascular and metabolic markers with the exception of FBG, with men having greater SBP and DBP and women having higher WC and TC on average. Women had significantly higher mean BMI (mean = 28.50 vs. 24.50, $p < 0.05$) and significantly higher mean CBR scores than men (2.38 vs. 1.68, $p < 0.01$). No clustering was observed for the inflammatory marker asthma. There were no sex differences in neighbourhood exposures, with similar proportions of men and women having recreation or playing areas in their community and a similar mean neighbourhood disorder score (Table 1). Youth comprised approximately 4% of the participants. There were also significant age differences compared to adults for all the individual cardiovascular and metabolic markers, including mean FBG.

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.

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

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

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

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]

It is possible medication use may have decreased CBR due to a shift of biomarkers below the high risk cut points or increased it among the young, for whom taking medication would indicate that some systemic dysregulation has already occurred.[4] Additionally, the neighbourhood was defined as an ED, many of which are heterogeneous. It is quite 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. We also had no information on the interrater reliability of neighborhood assessments, given the existing nature of the data and timeframe since data collection. While we assume, given the information on training of interviewer perceptions, that the reliability was high, there was no way to test this. Finally, we have no data on lifetime history or risk factors (e.g. trauma or abuse, childhood socioeconomic status, birthweight or childhood nutrition) that may also impact CBR in adulthood.

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

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

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.

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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.

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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

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 ≥ 110 mg/dL and BMI ≥ 25 kg/m^2; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or ≥ 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.

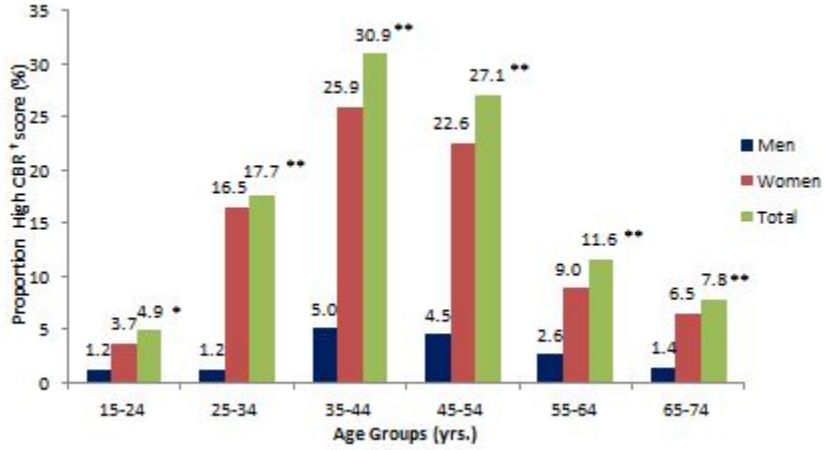
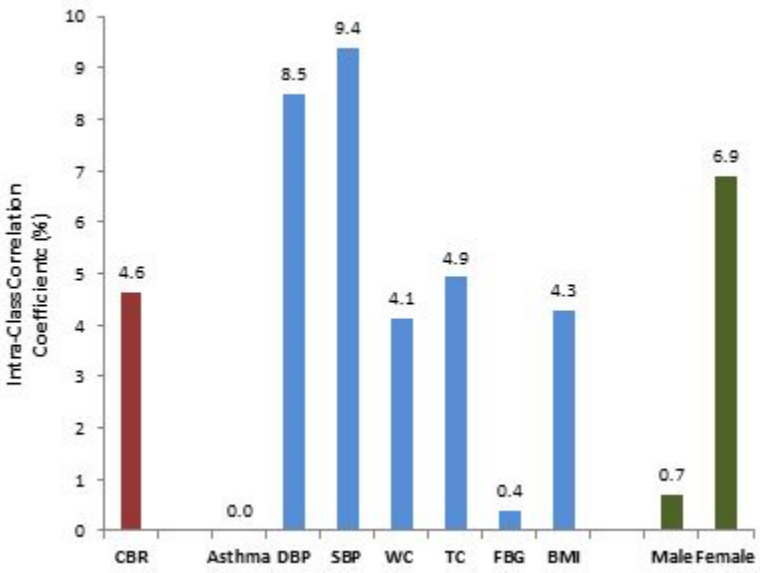


Figure 1 Proportion High CBR† score by age and sexCBR – Cumulative Biological Risk †High CBR was defined as at least one standard deviation above the mean score. *p < 0.01,** and **p < 0.0001 comparing sex differences within each age group

35x19mm (300 x 300 DPI)



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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.

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

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

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

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

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

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

Through a secondary analysis of the JHLS II dataset, we examined the relation between neighbourhood conditions—specifically, neighbourhood disorder and availability of recreational

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 10^{th} 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

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. [50] It has been used in previous studies assessing CBR. [37]

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, [36] ≥ 25 kg/m2 for BMI, > 6.2 mM/L for TC levels [51] and ≥ 110 mg/dL (6.1mmol/L) for FBG levels. [52] CBR was examined as both a continuous and a dichotomous variable. 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 (self-reported asthma included). 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. [53]

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

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). Household crowding was also examined as a potential confounder, defined as both more than one person per habitable room as well as the average number of individuals per habitable room. A complete list is documented in the technical report. [39]

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.

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, and therefore higher total scores indicated greater neighbourhood disorder. While there are no gold standard measures for neighbourhood disorder, indices representing both social and physical disorder in communities have been widely employed and utilizing both self-reported or perceived as well as objective measures.[19, 54-56] Some have included only markers of physical disorder, as is the case in the present study and a limitation; however, physical disorder has been closely linked to social disorder but may not necessarily be a marker of social disorder.[57-59] Nonetheless, physical disorder may contribute to biologic stress markers such as CBR, irrespective of social disorder.

Recreational areas/playing fields/opens spaces availability in the participant's neighbourhood was also assessed 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. Responses where an interviewer indicated an inability to assess or was unsure were excluded from the analysis at the individual level. Eight percent of respondents were missing data on neighbourhood-level items; however, those excluded did not differ in any way from those included in the analysis. Both disorder and recreational availability were individual-level measures, assessed based on the participant's home and immediate walking area around the home; therefore, missing data was only at the level of the individual and not the ED.

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} / VED + $V_{individual}$) X 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 framework. [60] Since the outcome variable is binary, the ICC was calculated using Snijders formula where $V_{student} = \prod 2 / 3$. [61, 62]

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

Ethical Approval

Ethical approval was received from the Ministry of Health, Jamaica and the University Hospital of the West Indies.

RESULTS

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

significantly higher mean BMI (mean = 28.50 vs. 24.50, $p < 0.05$) and significantly higher mean CBR scores than men (2.38 vs. 1.68, $p < 0.01$). No clustering was observed for the inflammatory marker asthma. There were no sex differences in neighbourhood exposures, with similar proportions of men and women having recreation or playing areas in their community and a similar mean neighbourhood disorder score (Table 1). Youth comprised approximately 4% of the participants. There were also significant age differences compared to adults for all the individual cardiovascular and metabolic markers, including mean FBG.

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.

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} + $V_{individual}$) X 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

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

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

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

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 including factors beyond socioeconomic status, on biologic stress in a middle-income country context. In addition, this study provided a large sample size representative of Jamaicans 15 to 74 years. Utilization of a multilevel approach and examination of cumulative biologic risk in this context is another strength. 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. 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, 76] 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] Additionally, the neighbourhood was defined as an ED, many of which are

heterogeneous. It is quite 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. We also had no information on the interrater reliability of neighborhood assessments, given the existing nature of the data and timeframe since data collection. While we assume, given the information on training of interviewer perceptions, that the reliability was high, there was no way to test this.

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

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

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.

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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.

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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

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 ≥ 110 mg/dL and BMI ≥ 25 kg/m^2; for youth <18 years old high risk cut points used were > 1 standard deviation above the mean for their age and sex or ≥ 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.

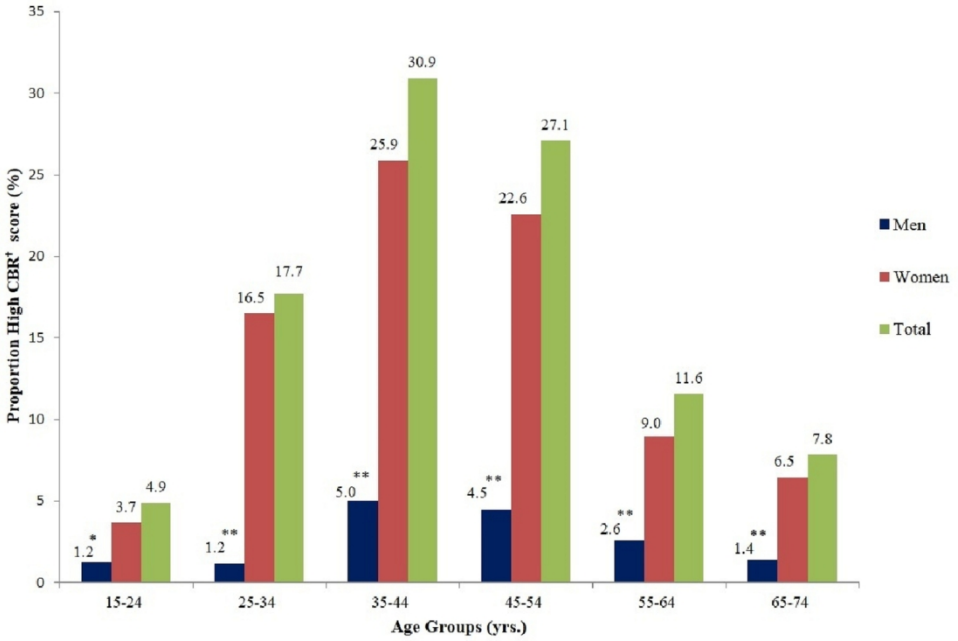

Figure 1. Proportion High CBR score by age and sex. CBR, Cumulative Biological Risk; †High CBR was defined as at least one standard deviation above the mean score.
*P < 0.01; **P < 0.0001

140x93mm (300 x 300 DPI)

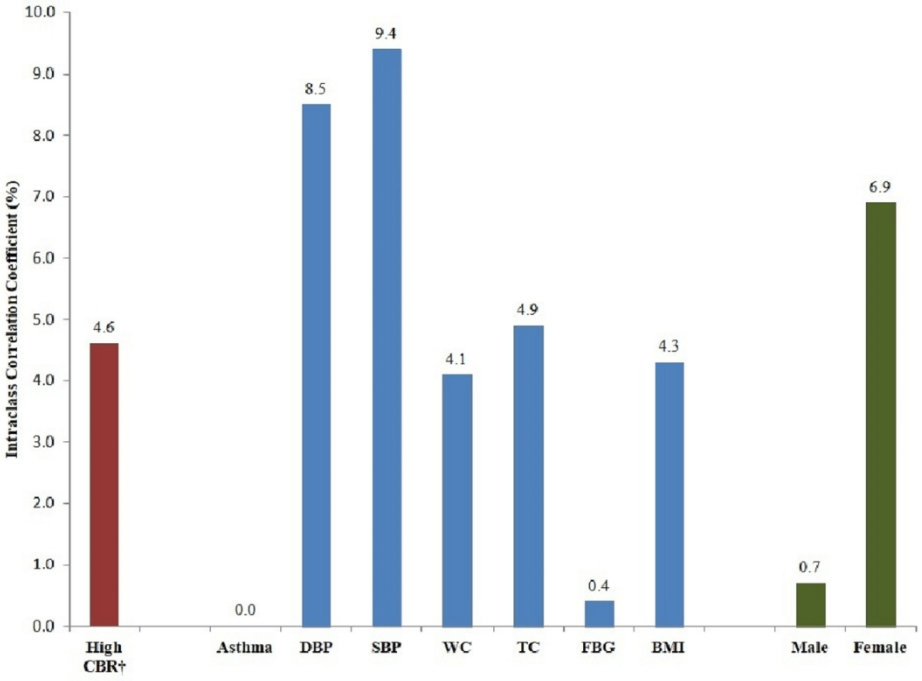

Figure 2. Neighbourhood clustering (Intraclass Correlation Coefficient, ICC%) of High Cumulative Biologic Risk (CBR)* by individual biomarkers** and sex.

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.
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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.