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Short communication

The association between adverse childhood experiences, neighborhood greenspace, and body mass index: A cross-sectional study

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ABSTRACT

An association between adverse childhood experiences (ACEs) and elevated body mass index (BMI) has been found in previous investigations. ACEs' effects on BMI have been primarily considered via individual-level physiological and behavioral frameworks. Neighborhood factors, such as greenspace, are also associated with BMI and may merit consideration in studies examining ACEs-BMI associations. This exploratory study examined associations of BMI with ACEs and neighborhood greenspace and tested whether greenspace moderated ACEs-BMI associations. Methods entailed secondary analysis of cross-sectional data. ACEs and BMI were captured from 2012/2013 Philadelphia ACE Survey and 2012 Southeastern Household Heath Survey data; greenspace percentage in participants' ($n = 1,679$ adults) home neighborhoods was calculated using National Land Cover Database data. Multi-level, multivariable linear regression 1) examined associations between BMI, ACEs, (0 ACEs [reference], 1–3 ACEs, 4 + ACEs), and neighborhood greenspace levels (high [reference], medium, low) and 2) tested whether greenspace moderated the ACEs-BMI association (assessed via additive interaction) before and after controlling for sociodemographic and health-related covariates. Experiencing 4 + ACEs ($\beta = 1.21$; 95 %CI: 0.26, 2.15; $p = 0.01$), low neighborhood greenspace ($\beta = 1.51$; 95 %CI: 0.67, 2.35; $p < 0.01$), and medium neighborhood greenspace ($\beta = 1.37$; 95 %CI: 0.52, 2.21; $p < 0.01$) were associated with BMI in unadjusted models. Only low neighborhood greenspace was associated with BMI ($\beta = 0.95$; 95 %CI: 0.14, 1.75; $p = 0.02$) in covariate-adjusted models. The ACEs-greenspace interaction was not significant in unadjusted ($p = 0.89$–0.99) or covariate-adjusted ($p = 0.46$–0.79) models. In conclusion, when considered simultaneously, low neighborhood greenspace, but not ACEs, was associated with BMI among urban-dwelling adults in covariate-adjusted models.

1. Introduction

Adverse childhood experiences (ACEs) are traumatic events that occur prior to age 18, such as experiencing physical or sexual abuse, witnessing violent crime, domestic violence against a female caregiver, or incarceration of a parent (Cronholm et al., 2015; Felitti et al., 1998). Prior research has demonstrated an association between ACEs and obesity (defined as body mass index [BMI] of ≥ 30 kg/m^2) during adulthood, likely due to immunometabolic, neuroendocrine, psychosocial, and behavioral stress responses that promote higher BMI (Felitti et al., 1998; Wiss and Brewerton, 2020; Hantsoo and Zemel, 2021). Factors at higher levels of ecology, such as aspects of neighborhood environment, are infrequently studied in ACEs research, although exposure to community-level ACEs have been shown to impact health behaviors and outcomes (Wade et al., 2016).

Neighborhood greenspace, defined as space including natural vegetation and used for aesthetics or recreation, is associated with reduced risk of obesity (De la Fuente et al., 2021). Greenspace's inverse

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association with BMI is hypothesized to occur through several possible pathways, including increased physical activity, decreased stress, improved mental health, greater social interaction, and beneficial immunometabolic effects of biodiverse microbial input from natural environments (Wendelboe-Nelson et al., 2019; Rook, 2013; Twohig-Bennett and Jones, 2018).

Considered collectively, prior evidence documents that both ACEs and greenspace are associated with BMI. It is plausible that greenspace's beneficial effects on psychosocial well-being, physical activity, and immunometabolic health could potentially modify the negative effects of ACEs; thus, previously reported associations between ACEs and obesity may differ based on greenspace exposure. Additionally, ACEs, greenspace, and obesity have all been linked to social determinants of health (SDH), with marginalized communities having higher rates of obesity (Wang et al., 2020) and ACEs burden (Cronholm et al., 2015) and lower amounts of greenspace (Nesbitt et al., 2019; Rigolon et al., 2021). However, prior research is limited in that studies have examined ACEs and greenspace separately, not simultaneously, leaving unanswered questions about concurrent associations with BMI. Thus, this exploratory study reported examined associations of BMI with ACEs and greenspace and tested whether greenspace moderated ACEs-BMI associations, before and after controlling for potential confounders that include common SDH.

2. Methods

Secondary analysis of cross-sectional survey data and publicly available spatial data was conducted. Institutional Review Board approval was received, including waiver of consent. The sample included participants in the 2012 Southeastern Pennsylvania Household Heath Survey (HHS) (Public Health Management Corporation, 2021) and add-on Philadelphia ACE Survey, telephone surveys collected from 11/2012 to 1/2013 with 1,784 randomly selected adults (≥18 years) living in Philadelphia, Pennsylvania in the United States of America. Details are reported elsewhere (Cronholm et al., 2015; Wade et al., 2016). This analysis sample was limited to participants for whom residence census tract (the smallest level of geographic information in the data) was available (n = 1,679).

2.1. Measures

Measures included ACEs, BMI, greenspace, and potential confounders; all are detailed in this section. The Philadelphia ACE survey (Cronholm et al., 2015; Wade et al., 2016) was developed by an expert task force, grounded in prior literature, informed by qualitative research with Philadelphia youth, and adapted from existing tools for assessing ACE exposure (Cronholm et al., 2015). Nine household-level and five community-level ACEs were assessed. The nine household-level ACEs were: physical, emotional, and sexual abuse; physical and emotional neglect; witnessing domestic violence; substance use, incarceration, or mental illness of a household member; the five community-level ACEs were: witnessing community violence; racial/ethnic discrimination; low neighborhood safety; bullying; and foster care. For this analysis, ACEs were dichotomized (yes/no), summed, and categorized (0 ACEs, 1–3 ACEs, or 4 + ACEs) per evidence demonstrating meaningful thresholds for ACEs-related health risks (Wade et al., 2016; Hughes et al., 2017). BMI and potential confounders were from the HHS. BMI was calculated per self-reported height and weight, examined for normality of distribution, and treated as a continuous variable.

Greenspace was obtained via 2013 National Land Cover Database (NLCD) (Data.gov. National Land Cover Database (NLCD) Percent Developed Imperviousness Collection., 2018) data. The NLCD is a gridded 30 meter by 30 meter pixel database maintained by the United States Geological Survey and coordinated by the 10-member Multi Resolution Land Characteristics Consortium, an interagency federal government collaboration. NLCD data can be used to measure greenspace (Data.gov., 2018; Akpinar et al., 2016). Using thematic mapper imagery, the NLCD categorizes landcover into 20 classes, including open water, barren land, developed high intensity, deciduous forest, evergreen forest, shrub/scrub, and cultivated crops. For this study, landcover classes were defined as greenspace or not greenspace based on methods tailored for urban environments used in prior research, in order to capture not only commonly recognized greenspaces (e.g., forest canopy) but also diverse greenspaces relevant to urban settings (e.g., parks, large yards/gardens, vegetation planted for recreation) (Akpinar et al., 2016). Details of landcover classification are listed in Appendix Table A.1. Percent of greenspace in the census tract of each participant's current home residence was then calculated, and census tracts were categorized by greenspace tertiles (high [≥30.7 %], medium [7.63–30.6 %], or low [≤7.62 %] greenspace). Greenspace data was prepared using ESRI ArcGIS 10.8.

Covariates included sociodemographic and health-related potential confounders, some of which comprise common SDH: age (categorical: 18–34 [reference], 35–65, 65 +), sex (categorical: male [reference], female), race (categorical: Asian, Black, Hispanic, other, White [reference]), below 150 % Federal poverty threshold (categorical: yes or no [reference]), marital status (categorical: married/partnered [reference], other, separated/widowed/divorced, single), employment status (categorical: employed [reference], other, retired, unemployed), education level (categorical: less than high school, high school/technical, some or all college, graduate school), chronic diagnosis (categorical: yes or no [reference] for hypertension/stroke/asthma/cancer/human immunodeficiency virus/chronic obstructive pulmonary disease/diabetes mellitus), and sexarche (continuous). Covariates were selected based on prior research demonstrating an association with BMI and ACEs (Wang et al., 2020; Song and Qian, 2020; Epstein et al., 2018; Crouch et al., 2019; Walsh et al., 2019).

2.2. Statistical analysis

Analyses include descriptive statistics to examine sample characteristics, chi-square test to examine differences in greenspace by ACE exposure, and multi-level, multivariable linear regression accounting for census tract-level clustering to examine associations among ACEs, BMI, and potential confounders. Unadjusted and adjusted models estimating BMI included the following independent variables: Model 1) ACEs and greenspace; Model 2) ACEs, greenspace, and an ACEs-greenspace additive interaction term with the lowest joint risk group (0 ACEs and high greenspace) as reference. Estimated BMI values were assessed for each level of ACE-greenspace exposure. Standard model diagnostics were assessed for all models, including variance inflation factor to ensure lack of collinearity. Analyses were conducted using RStudio 4.1.0. Survey weights created for the original Philadelphia ACE Survey were not used in this secondary multi-level analysis; instead, variables comprising survey weights (age, sex, race, poverty) were included along with additional potential confounders mentioned above. Therefore, findings should be considered representative of the study sample, not the broader Philadelphia population.

During the peer-review process, two post-hoc exploratory analyses were executed to assess robustness of study findings. The first repeated Model 1, but operationalized ACEs as two separate variables: household-level continuous ACE score (range: 0–9) and community-level continuous ACE score (range: 0–5). The second repeated Model 1, but included fewer confounders (only age, sex, race, and education level).

3. Results

The sample included 1,679 participants. Collectively, 327 (19.5 %) participants experienced 0 ACEs, 803 (37.8 %) experienced 1–3 ACEs, and 549 (32.7 %) experienced 4 + ACEs. Most identified as female (n = 1,218 [72.5 %]), Black (n = 747 [44.5 %]) or White (n = 787 [46.9 %]), and were 36–65 years old (n = 1,017 [60.5 %]). Participants' mean BMI was 29.3 ± 6.8 kg/m^2. Participants' census tracts included 25.3 ± 25.1 % greenspace. Individuals with higher ACE exposure lived in neighborhoods with lower greenspace (mean neighborhood greenspace 29.1 % for participants 0 ACEs, 25.9 % for 1–3 ACEs, and 22.3 % for 4 + ACEs [$p < 0.01$]). Full sample characteristics, for the total sample and by ACE exposure category, are presented in Appendix Table A.2.

Unadjusted and adjusted multi-level, multivariable linear regression results are presented in Table 1. In unadjusted models, greater ACE exposure and less greenspace were associated with higher BMI. More specifically, experiencing 4 + ACEs (β = 1.21; 95 %CI: 0.26, 2.15; p = 0.01) versus 0 ACEs and residing in a neighborhood with low greenspace (β = 1.51; 95 %CI: 0.67, 2.35; $p < 0.01$) or medium greenspace (β = 1.37; 95 %CI: 0.52, 2.21; $p < 0.01$) versus high greenspace were independently associated with BMI. After adjusting for potential confounders noted above, ACE exposure was no longer associated with higher BMI, but the association between low greenspace and higher BMI remained (β = 0.95; 95 %CI: 0.14, 1.75; p = 0.02). Findings of post-hoc exploratory analyses were consistent with that of primary a priori analyses (Appendix Table A.3-A.4).

Analyses did not demonstrate an additive interaction between ACEs and greenspace (Table 1, Model 2a-2b). Table 2 includes BMI estimates for each ACE-greenspace exposure level after controlling for potential confounders.

Table 1
Unadjusted and adjusted multi-level, multivariable linear regression models predicting BMI[a.]

	Estimate (95 % confidence interval)	p-value
Model 1a: BMI = ACE score + greenspace		
ACE score (Reference: 0 ACEs)	0.60	
1–3 ACEs	(-0.28, 1.48)	0.19
4 + ACEs	**1.21 (0.26, 2.15)**	**0.01**
Greenspace (Reference: High greenspace)		
Low	**1.51 (0.67, 2.35)**	**<0.01**
Medium	**1.37 (0.52, 2.21)**	**<0.01**
Model 1b: BMI = ACE score + greenspace + confounders[a]		
ACE score (Reference: 0 ACEs)	0.05	
1–3 ACEs	(-0.84, 0.95)	0.93
4 + ACEs	−0.12 (-1.10, 0.86)	0.80
Greenspace (Reference: High greenspace)		
Low	**0.95 (0.14, 1.75)**	**0.02**
Medium	0.64 (-0.15, 1.44)	0.10
Model 2a: BMI = ACE score + greenspace + ACE score*greenspace		
ACE score (Reference: 0 ACEs)	0.64	
1–3 ACEs	(-0.79, 2.07)1.33	0.38
4 + ACEs	(-0.27, 2.93)	0.11
Greenspace (Reference: High greenspace)	1.58	
Low	(-0.25, 3.42)1.47	0.09
Medium	(-0.32, 3.26)	0.11
Greenspace tertiles*ACE score (Reference: High greenspace*0 ACEs)		
Low greenspace*4 + ACEs	−0.04 (-2.36, 2.27)	0.97
Low greenspace*1–3 ACEs	−0.14 (-2.29, 2.01)	0.89
Medium greenspace*4 + ACEs	−0.34 (-2.63, 1.95)0.02	0.77
Medium greenspace*1–3 ACEs	(-2.10, 2.14)	0.99
Model 2b: BMI = ACE score + greenspace + ACE score*greenspace + confounders[a]		
Greenspace (Reference: High greenspace)	1.45	
Low	(-0.38, 3.29)1.05	0.12
Medium	(-0.72, 2.81)	0.24
ACE score (Reference: 0 ACEs)	0.45	
1–3 ACEs	(-0.97, 1.90)0.14	0.55
4 + ACEs	(-1.47, 1.74)	0.88
Greenspace tertiles*ACE score (Reference: High greenspace*0 ACEs)		
Low greenspace*4 + ACEs	−0.33 (-2.63, 1.96)	0.79
Low greenspace*1–3 ACEs	−0.54 (-2.98, 1.32)	0.65
Medium greenspace*4 + ACEs	−0.83 (-2.77, 1.70)	0.46
Medium greenspace*1–3 ACEs	−0.46 (-2.57, 1.64)	0.68

Note: ACE = adverse childhood experience, BMI = body mass index. Boldface = statistical significance ($p < 0.05$).

[a] Confounders adjusted for include age (categorical: 18–34 [reference], 35–65, 65 +), sex (categorical: male [reference], female), race (categorical: Asian, Black, Hispanic, other, White [reference]), below 150 % Federal poverty threshold (categorical: yes or no [reference]), marital status (categorical: married/partnered [reference], other, separated/widowed/divorced, single), employment status (categorical: employed [reference], other, retired, unemployed), education level (categorical: less than high school, high school/technical, some or all college, graduate school), chronic disease diagnosis (categorical: yes or no [reference] for hypertension/stroke/asthma/cancer/human immunodeficiency virus/chronic obstructive pulmonary disease/diabetes mellitus), and age at first sexual activity (continuous).

4. Discussion

The exploratory study is, to our knowledge, the first to examine the association of ACEs, BMI, and greenspace among urban-dwelling adults and to explore BMI differences across levels of ACE-greenspace exposures. Results demonstrated that experiencing 4 + ACEs and low or medium neighborhood greenspace were independently associated with

Table 2
Estimated BMI for each level of ACEs-greenspace exposure.

Group	Estimated BMI	Standard error	95 % confidence limit
Model 1b – BMI = ACE score + greenspace + confounders[a]			
4 + ACEs * high greenspace	27.3	0.676	26.0 28.7
0 ACEs * high greenspace	27.5	0.742	26.0 28.9
1–3 ACEs * high greenspace	27.5	0.676	26.2 28.8
4 + ACEs * medium greenspace	28.0	0.657	26.7 29.3
0 ACEs * medium greenspace	28.1	0.736	26.7 29.6
1–3 ACEs * medium greenspace	28.2	0.670	26.7 29.3
4 + ACEs * low greenspace	28.3	0.649	27.0 29.6
0 ACEs * low greenspace	28.4	0.726	27.0 29.8
1–3 ACEs * low greenspace	28.5	0.654	27.2 29.7
Model 2b – BMI = ACE score + greenspace + ACE score*greenspace + confounders[a]			
0 ACEs * high greenspace	27.2	0.850	25.5 28.9
4 + ACEs * high greenspace	27.3	0.778	25.8 28.9
1–3 ACEs * high greenspace	27.6	0.715	26.2 29.0
4 + ACEs * medium greenspace	27.8	0.724	26.4 29.3
0 ACEs * medium greenspace	28.2	0.891	26.5 30.0
1–3 ACEs * medium greenspace	28.2	0.720	26.8 29.6
1–3 ACEs * low greenspace	28.3	0.699	26.9 29.6
4 + ACEs * low greenspace	28.5	0.715	27.0 29.9
0 ACEs * low greenspace	28.6	0.920	26.8 30.4

Note: ACE = adverse childhood experience, BMI = body mass index.

[a] Confounders adjusted for include age (categorical: 18–34 [reference], 35–65, 65 +), sex (categorical: male [reference], female), race (categorical: Asian, Black, Hispanic, other, White [reference]), below 150 % Federal poverty threshold (categorical: yes or no [reference]), marital status (categorical: married/partnered [reference], other, separated/widowed/divorced, single), employment status (categorical: employed [reference], other, retired, unemployed), education level (categorical: less than high school, high school/technical, some or all college, graduate school), chronic disease diagnosis (categorical: yes or no [reference] for hypertension/stroke/asthma/cancer/human immunodeficiency virus/chronic obstructive pulmonary disease/diabetes mellitus), and age at first sexual activity (continuous).

higher BMI in unadjusted models. However, after adjusting for potential confounders identified above, low greenspace but not ACEs, remained associated with higher BMI. Results did not demonstrate a statistically significant additive interaction between ACEs and greenspace.

Prior landmark research by Felitti and colleagues showed a dose response between ACEs and obesity and recent systematic reviews include a number of studies that have explored and often confirmed the ACE-obesity relationship (Felitti et al., 1998; Wiss and Brewerton, 2020; Hughes et al., 2017). We did not find the same association between ACEs and higher BMI after controlling for neighborhood greenspace and potential confounders, which could be due to a number of factors. First, several prior studies used measured heights and weights and/or dichotomized BMI into $\geq$30 kg/m^2 to align with a diagnosis of obesity, whereas we used self-reported heights and weights to compute BMI, and we analyzed BMI as a continuous outcome to maintain the measure's granularity. Second, much early ACEs research measured household-level ACEs only, but the field has grown to understand that adversities outside the home can also impact health and behaviors. This study's 14-item ACE score captures both household and community-level ACEs, some of which are known SDH, such as witnessing community violence, racial discrimination, and perceptions of neighborhood safety (Cronholm et al., 2015; Wade et al., 2016). Of note, our post-hoc analyses examining household and community-level ACEs separately did not change our study findings. However they did demonstrate that community-level ACEs but not household-level ACEs were associated with higher BMI in unadjusted analyses. While not the focus of the current study, the finding does highlight the importance of exploring the differences between household versus community-level ACEs in future work examining ACEs-BMI associations, including how to disentangle their effects from one another and how to disentangle effects of community-level ACEs from SDH. Third, this study also sampled from a more racially diverse and socioeconomically disadvantaged population and adjusted for a broader array of potential confounders than the landmark ACE study that controlled for age, sex, race and educational attainment (Felitti et al., 1998). Interestingly, post-hoc exploratory analyses controlling for only the same variables as the landmark ACE study did not change our study findings. It is unclear why this is the case, though we hypothesize that differences between our study and the landmark studies' samples (beyond the differences captured in the aforementioned covariates) may have led to the difference in findings. Lastly, greenspace may have served as a proxy for other neighborhood-level SDH in our study, given prior literature that shows under-resourced neighborhoods have less greenspace (Nesbitt et al., 2019; Rigolon et al., 2021). Some of these study differences would reduce bias, while others might increase bias in this study's ACEs-BMI association estimates. Therefore, it is important to replicate this exploratory study's findings in other samples to better understand ACEs-BMI and ACEs-obesity associations, particularly while controlling for greenspace or other neighborhood-level potential confounders.

Greenspace was independently associated with BMI after adjusting for potential confounders, regardless of ACE exposure. There are various plausible mechanisms for the greenspace-BMI connection. Greenspace is associated with lower rates of depression, anxiety, and stress, all of which have been correlated with lower engagement in physical activity and higher levels of obesity (De la Fuente et al., 2021; Wendelboe-Nelson et al., 2019). Well-maintained, safe neighborhood greenspace may promote healthy body weight by increasing physical activity and thereby provide secondary benefits to mental health and well-being (Wendelboe-Nelson et al., 2019; Rook, 2013; Twohig-Bennett and Jones, 2018). Other beneficial effects of greenspace, such as increased social cohesion and exposure to biodiverse microorganisms that support immunometabolic health, may be equally relevant to reducing BMI (Rook, 2013; Twohig-Bennett and Jones, 2018). Additionally, given inequities in access to greenspace by factors such as race as socioeconomic status, it is possible that greenspace is a proxy for broader neighborhood-level SDH that influence BMI; in our study, we attempted to help account for this by controlling for potential individual-level confounders such as race, education, and poverty, but more work is needed to tease apart the role of other SDH.

A potential moderation of greenspace on the ACEs-BMI association was tested based upon two hypotheses. First, individuals affected by ACEs living in a high greenspace neighborhood might have lower BMI, as prior research has identified greenspace's beneficial effects on BMI via physical activity, stress, mental health, social interaction, and immunometabolism (Wendelboe-Nelson et al., 2019; Rook, 2013; Twohig-Bennett and Jones, 2018). Second, greenspace could buffer ACEs' stress-related effects on BMI. Evidence suggests ACEs' association with higher BMI occurs via stress pathways (Felitti et al., 1998; Wiss and Brewerton, 2020; Hantsoo and Zemel, 2021). Greenspace is associated with lower rates of stress, stress-related mental health conditions, and better mental well-being (De la Fuente et al., 2021; Wendelboe-Nelson et al., 2019). Thus we hypothesized that living in a neighborhood with higher greenspace might buffer ACEs' harmful stress-related mental health effects on BMI. Despite these hypothesized pathways, findings did not demonstrate a moderation effect.

There are several potential explanations for not finding a moderation effect. First, characteristics of greenspace that were not assessed in this study (e.g., safety, quality, accessibility) are salient to how persons who experienced ACEs engage with greenspace. For example, a moderation effect might exist for safe, well-maintained, accessible greenspace, but not all greenspace. These characteristics might be particularly salient in places that demonstrate wide variation in greenspace quality; for example, in many urban areas some greenspaces are lush, well-maintained parks with minimal crime and other greenspaces are poorly maintained grass lots in areas of higher crime with characteristics associated with neighborhood disorder (e.g., litter, blight). Others are privately accessed. Second, specifics of the study, such as its cross-sectional nature or how measures were operationalized, may have limited the ability to detect a moderation effect that might indeed exist. Lastly, a moderation effect may not exist. The associations of greenspace and ACEs with BMI may operate independently, especially after accounting for SDH. The effects of both greenspace and ACEs on BMI are complex, multi-faceted, and modest; hypothesized effects of ACEs and greenspace may be similar but not identical. Thus, it is possible that our findings reveal that they do not interact to influence BMI.

Interestingly, individuals with higher ACE exposure lived in neighborhoods with lower greenspace. Additionally, given that we did not find a significant association between ACEs and BMI in multivariate analyses, but prior research has found a significant association (Felitti et al., 1998; Wiss and Brewerton, 2020; Hughes et al., 2017), it is possible that controlling for greenspace in those prior studies would have reduced or eliminated that association. Therefore, including greenspace in future ACEs-obesity research could help clarify these associations. In addition, future greenspace-ACEs-obesity research should heed attention to measurement issues arising from wide variation in operationalization of both ACEs and obesity. For example, studies that include sensitivity analyses testing how different measures of greenspace (e.g., park access versus greenspace per tract), aspects of greenspace (e.g., safety, quality, access), or different operationalization of ACEs (e.g., continuous versus categorical ACE scores) can further illuminate associations.

4.1. Limitations

Limitations of the study include: being a cross-sectional secondary analysis of existing data, inability to infer causality; using self-reported ACEs and BMI data; and assuming that census tract is an appropriate scale of measurement for neighborhood exposure. Additionally, results may not generalize outside one urban setting or to studies that operationalize ACEs and greenspace differently. Also green space type, features, and quality were not assessed. Finally, it is possible that analyses may be biased due to omission of potential confounders, including unmeasured individual- or neighborhood-level SDH, that we were unable to examine given limitations in the data.

5. Conclusions

After accounting for key sociodemographic and health-related factors, low neighborhood greenspace, but not ACEs, was independently associated with BMI. Currently, most efforts to understand and address documented ACEs-obesity associations have focused at lower levels of the socio-ecological model. Future research should examine why the previously observed association between ACEs and BMI was disconfirmed in this study, after accounting for SDH-related potential confounders and greenspace.

CRediT authorship contribution statement

Krista Schroeder: Conceptualization, Methodology, Funding acquisition, Writing – original draft. **Christine M. Forke:** Conceptualization, Methodology, Writing – review & editing. **Jennie G. Noll:** Conceptualization, Funding acquisition, Writing – review & editing. **David C. Wheeler:** Methodology, Writing – review & editing. **Kevin A. Henry:** Methodology, Writing – review & editing. **David B. Sarwer:** Conceptualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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