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A longitudinal analysis of relationships between neighborhood context and underserved children's physical activity in a rapidly growing city

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ABSTRACT

Neighborhood context, which may be impacted by urban growth or residential mobility, is associated with childhood physical activity. This secondary analysis examined associations of objectively measured neighborhood characteristics with young children's moderate-to-vigorous physical activity (MVPA) and sedentary/rest time (SRT) over a period of rapid infrastructure change.

Underserved preschoolers (n = 426) from a 36-month obesity prevention intervention were included in a secondary analysis (2019–2020). Based on household addresses, participants were coded as movers or non-movers and linked to four neighborhood variables: 1) distance to recreation sites, 2) annual crimes, 3) annual stray dogs, and 4) Gini index of income inequality. Accelerometry captured MVPA and SRT at baseline and 36 months. Baseline-to-follow-up neighborhood variables within moved and non-moved groups were compared. Multivariable regression assessed associations between follow-up MVPA/SRT and neighborhood variables.

45.3% of participants (n = 193) moved. Distance to the closest recreation site decreased significantly for non-movers (0.75 to 0.72 mi, $p < 0.001$). Nearby crimes significantly decreased for both groups (movers: 90 to 80, $p < 0.001$; non-movers: 77 to 74, $p < 0.001$) as did stray dogs (movers: 36 to 15, $p < 0.001$; non-movers: 36 to 18, $p < 0.001$). Neighborhood income inequality decreased significantly for movers (0.41 to 0.38, $p = 0.03$). Child MVPA minutes/day significantly decreased over time from median = 84.7 [Q1 = 64.1, Q3 = 103.9] to median = 73.6 [Q1 = 56.1, Q3 = 96.0], $p < 0.001$). No significant associations were detected between neighborhood variables and child physical activity.

In a rapidly growing county, neighborhood context generally improved over time regardless of move status. Within this context, no associations between neighborhood characteristics and MVPA/SRT were detected in children.

1. Introduction

The United States is experiencing a period of rapid demographic shifts and expansion of city infrastructure (Colby and Ortman, 2014; Casey et al. Dec 10, 2017). Along with this population shift to urban cores, there has been a renewed emphasis on civic investment in neighborhood-level infrastructure to support physical activity, including public recreation facilities and green spaces (Wolch et al., 2014). For example, in Davidson County, Tennessee, the setting of this study, the local government has targeted recreation infrastructure investments over the past decade, adding park square footage, greenways, and recreation centers (Harper, 2013). These investments are designed to improve physical activity patterns at a population level through improved neighborhood context, recognizing that the majority of the U.S. population does not regularly meet physical activity guidelines (Tremblay et al., 2016). These unhealthy behavior patterns are especially problematic for children, promoting excessive weight gain during childhood and increasing a lifetime risk of premature mortality, cardiovascular disease, diabetes, mental disorders, and certain cancers (Thorp et al., 2011). Although sedentary behavior-related health outcomes typically do not manifest until adolescence or adulthood, physical activity patterns set in early childhood predict physical activity later in

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life (Kwon et al., 2015).

Neighborhood context encompasses multiple socioecological factors, including the built environment, neighborhood safety, and neighborhood socioeconomic status (SES) (Johnson et al., 2019; Kim and Cubbin, 2017; Heerman et al., 2016). Access to recreation sites is frequently used as a tool to evaluate children's built environment in research (Johnson et al., 2019). Neighborhood-level safety issues including crime and stray dogs (concerns reported by our study participants) may reduce children's interactions with the built environment and lead to decreased physical activity, although more research is necessary to evaluate mediators between objective and perceived neighborhood safety (Heerman et al., 2016). Prior research has also found that neighborhood income inequality may impact physical activity in poor children more than neighborhood income levels, with poor children in non-poor and unequal neighborhoods displaying the lowest physical activity levels, potentially due to social barriers (Kim and Cubbin, 2017). HYPERLINK "SPS:refid::bib9"

Residential mobility (moving) is an additional source of variability in neighborhood context. This is particularly relevant in the context of health disparities, as low-income families may be forced to move due to neighborhood gentrification (Root and Humphrey, 2014). Hispanic children, who experience higher rates of obesity and insufficient physical activity than their peers, may also experience higher rates of residential mobility than non-Hispanic white children (Hales et al., 2017; Brewer and Kimbro, 2014; Sharifi et al., 2016; United States Census Bureau, 2010). Due to the residential displacement associated with urban growth, local investments in recreation infrastructure may impact underserved families in unexpected ways. Given these factors, establishing the most salient neighborhood-level determinants of early child physical activity in minority populations while accounting for residential mobility has the potential to inform policies to reduce health disparities.

For young children, neighborhood context is commonly evaluated by parental report of both household characteristics (e.g., income) and neighborhood characteristics (e.g., perceived safety). While parental perception of various neighborhood contextual factors has been associated with childhood physical activity patterns, these studies often lack an objective evaluation of the neighborhood context (Sallis and Glanz, 2006; van Bakergem et al., 2017; Soltero et al., 2017; Kneeshaw-Price et al., 2015). Expanding our understanding with objective measures could direct interventions to more effectively support childhood physical activity and reduce health disparities.

Establishing associations between objective neighborhood contextual factors and child physical activity patterns is challenging because an individual's neighborhood context is dynamic due to both neighborhood-level changes and residential mobility. The current literature on neighborhood context and child physical activity patterns is largely based on cross-sectional studies that cannot adequately evaluate these dynamic factors (Johnson et al., 2019; Smith et al., 2017; McGrath et al., 2015). Therefore, this study sought to assess how objective measures of neighborhood context changed over time for a cohort of underserved children in a rapidly growing urban county, and the extent to which neighborhood context was associated with child physical activity. Neighborhood context was evaluated in four domains based on prior literature: household distance to the closest recreation site, annual crime, annual stray dogs, and neighborhood income inequality.

This study combined neighborhood-level public datasets with objective physical activity data collected longitudinally from a cohort of low-income, primarily Hispanic preschool-aged children to address several research questions in a secondary analysis: 1) How did neighborhood context change both within and between children who moved (movers) and children who did not move (non-movers) over the study period, and was this change statistically significant; and 2) Were there statistically significant associations between any of the four measures of neighborhood context and objective measures of child physical activity at study conclusion. It was hypothesized that movers would experience disadvantageous changes in neighborhood context over time and that non-movers would experience advantageous changes in neighborhood context over time. It was also hypothesized that each of the four neighborhood context factors would be significantly associated with child physical activity at the study conclusion.

2. Methods

2.1. Setting and participants

The Growing Right Onto Wellness (GROW) study was a 3-year randomized trial of 610 parent–child pairs from low-income, primarily Hispanic families in Nashville, TN (Po'e et al., 2013). The trial evaluated a behavioral intervention designed to prevent childhood obesity compared to an early literacy intervention. This study took place in Davidson County, TN from 2012 to 2017. During this period, Davidson County's neighborhood context changed due to rapid urban growth (Harper, 2013). Parent-child dyads were recruited from physicians' offices and community settings. Eligibility criteria included child 3–5 years old, baseline child BMI between the 50th and 95th percentiles (upper end of normal weight or overweight), parent $\geq$ 18 years old, parent and child ability to participate in physical activity, family eligibility for $\geq$ 1 form of government assistance, and English or Spanish speaking parent.

This staged-intensity intervention began with 12 weekly, 60-minute group sessions delivered by trained bilingual facilitators in local community centers. Participants then received monthly individualized health coaching calls for 9 months. Major topics included healthy diet, physical activity, sleep, media use, and parenting with a focus on goalsetting and self-monitoring. The final 24 months, intervention participants received cues to action to use their built environment to support nutrition and physical activity behaviors. The study's primary outcome was based on prospective measures of child BMI. Additional information about the GROW trial's eligibility criteria and methods has been published previously (Po'e et al., 2013). There was no statistical difference in BMI at 36 months between the intervention and comparator group (Barkin et al., 2018).

Eligibility criteria for this secondary analysis included baseline and follow-up objective physical activity measures and a home address within Davidson County, where sufficient data were available for all measured neighborhood characteristics.

2.2. Ethics approval

The study was approved by the Vanderbilt University Institutional Review Board, #120643. For the parent study, informed consent was obtained by trained bilingual research staff. This study presents a secondary analysis of the GROW cohort data linked with public datasets.

2.3. Dyad characteristics

Data on dyad demographics were collected by participant survey during the GROW RCT. Characteristics used in the current study include child age and sex, and parent age, sex, race/ethnicity, education level, employment status, marital status, and participation in the special supplemental nutrition program for women infants & children (WIC) or the supplemental nutrition assistance program (SNAP). Objectively measured BMI was also collected at baseline and 36 months (Po'e et al., 2013).

2.4. Address and residential mobility

Baseline household addresses were obtained by participant survey at baseline data collection for the original RCT (August 2012-May 2014). Follow-up addresses were captured for all participants at a single point

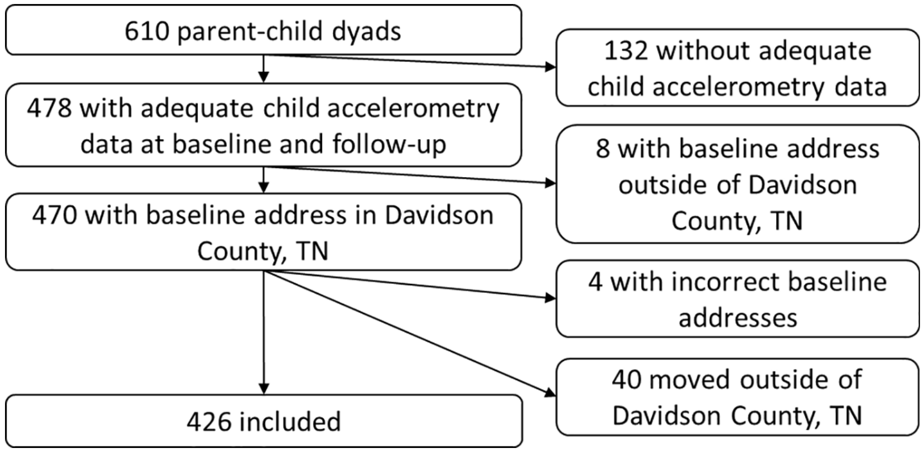

Fig. 1. Selection of cohort for GIS analysis from full GROW trial sample.

in time near the end of the study (August 2017). Addresses were mapped with ArcMap software (Esri ArcGIS, version 10.6.1) using the Esri North America StreetMap. Residential mobility from baseline to follow-up was coded for each participant. Among those whose address changed, straight line distance between baseline and follow-up addresses was calculated in ArcMap to determine how far participants moved in miles.

2.5. *Measuring neighborhood context*

Neighborhood context was evaluated using geographic information systems (GIS) in four domains: household distance to the closest recreation site, annual crime, annual stray dogs, and neighborhood income inequality. These domains were selected because they have been previously identified as contributors to child physical activity (Kim and Cubbin, 2017; Heerman et al., 2016). Participant addresses were linked to these data (Appendix Table 1). Baseline neighborhood data were obtained for 2012, when participant data collection began. Follow-up neighborhood data were obtained for 2016, as the most granular neighborhood data were available for this year. ArcMap was used to calculate network distance in miles to the closest recreation site (park, playground, greenway, community center, or pool) along Davidson County's street grid for each household. Network distance has been used previously to analyze distance to recreation sites and can be a more representative measure of accessibility than linear distance (Thornton et al., 2011).

To measure annual crime exposure, the number of personal safety crimes within a 0.5 mi straight line radius of each address was calculated in ArcMap (van Bakergem et al., 2017). Linear distance was used to measure crime exposure because it was theorized that proximity to crime might influence physical activity more than network distance (i.e., distance along roadways). To measure annual stray dog exposure, zip code-level stray dog counts were adjusted for zip code total land area (sq mi) and connected to addresses. Neighborhood income inequality, as measured by the Gini index, was connected with household addresses at the census tract level. A Gini index of 0 indicates perfect income equality, while an index of 1 indicates perfect income inequality (Lerman and Yitzhaki, 1984).

2.6. *Physical activity*

Accelerometry data were collected on all children and parents at baseline and 36 months using the ActiGraph GT3X + monitor. Participants were instructed to wear the monitor on the right hip for seven complete days, including during sleeping and water activity (e.g., bathing, swimming, showering). Wear-time criteria were developed by NIH's Childhood Obesity Prevention and Treatment Research Consortium and were 4 days (3 weekdays and 1 weekend day) of at least 6 h of activity 05:00–23:59. Before physical activity variables (including wear time and valid wear days) were derived, a previously validated algorithm was applied to remove nonwear time based on specific patterns of consecutive zero counts (Choi et al., 2011, 2012). The cut-points that categorized child movement into minutes of SRT and MVPA were based on previously validated algorithms for preschoolers (Butte et al., 2014). Percentage MVPA or SRT were computed by dividing mean daily minutes of MVPA or SRT by the total mean daily wear time.

2.7. *Statistical analyses*

The secondary analyses in this study occurred from 2019 to 2020. Participant baseline demographic variables, the four neighborhood context variables, and child physical activity measures at baseline and follow-up were summarized using univariate statistics.

The first research question about how neighborhood context changed over time both between and among movers and non-movers was addressed by two sets of analyses. In analysis set 1, to evaluate temporal changes, the four neighborhood context variables were compared at baseline and follow-up within the two residential mobility groups (movers and non-movers) using Wilcoxon sign-rank tests for paired data. In analysis set 2, neighborhood context was compared between movers and non-movers at baseline and at follow-up using Wilcoxon rank-sum tests. For completeness, baseline demographic variables and child physical activity measures at baseline and follow-up were also summarized and compared by residential mobility group using Wilcoxon rank-sum tests for continuous variables and chi-square tests for categorical variables. Previous reports have demonstrated that the intervention did not affect physical activity in children (Barkin et al., 2018).

The second research question about associations between the four measures of neighborhood context and objective measures of child physical activity at study conclusion was addressed by two additional sets of analyses. In analysis set 3, Spearman correlations were used to describe bivariate relationships between the four neighborhood context variables (closest recreation site distance, annual crime, annual stray dogs, and income inequality) and child mean daily minutes of SRT and MVPA. In analysis set 4, separate multivariable linear regression models analyzed the contemporaneous relationships between each of the key independent variables of interest (i.e., the four neighborhood context variables) and the two dependent outcome variables of child mean daily minutes of SRT and MVPA at follow-up. This resulted in a total of eight regression models (four for each of the two physical activity outcomes). The models analyzing child follow-up mean daily MVPA controlled for the following covariates: baseline percent MVPA, follow-up accelerometer wear time (minutes), child age (years), child sex (male or female), child BMI (kg/m^2), parent education (less than high school or completed

Table 1
Baseline demographic data for dyads, and baseline and follow-up physical activity data for children. Results presented as frequency (%) or median (Q1, Q3) and equality of groups was tested using a chi-square test or a Wilcoxon rank-sum test, respectively. Bolded values indicate significance at the 0.05 level.

	Combined (n = 426)	Movers (n = 193)	Non-movers (n = 233)	p-value
Parental age (years)	32.1 (28.0, 35.9)	31.2 (27.2, 35.2)	32.8 (28.7, 36.3)	**0.040**
Parental education				0.299
<High school graduate	260 (61.0)	123 (63.7)	137 (58.8)	
≥High school graduate	166 (39.0)	70 (36.3)	96 (41.2)	
Parental ethnicity				0.181
Hispanic Mexican	282 (66.2)	123 (63.7)	159 (68.2)	
Hispanic non-Mexican	110 (25.8)	48 (24.9)	62 (26.6)	
Non-Hispanic	34 (8.0)	12 (6.2)	22 (9.4)	
Employment status				0.709
Full time	73 (17.2)	36 (18.8)	37 (15.9)	
Part time	81 (19.1)	37 (19.3)	44 (18.9)	
Not employed	271 (63.8)	119 (62.0)	152 (65.2)	
Married or living as married	357 (83.8)	151 (78.2)	206 (88.4)	**0.005**
WIC/SNAP	370 (87.3)	172 (89.6)	198 (85.3)	0.193
Child age (years)	4.3 (3.6, 5.1)	4.4 (3.6, 5.0)	4.3 (3.6, 5.2)	0.827
Female child	217 (50.9)	111 (57.5)	106 (45.5)	**0.014**
Child baseline daily physical activity	n = 426	n = 193	n = 233	
Total wear time (minutes)	1080.2 (975.8, 1123.3)	1082.4 (964.0, 1123.7)	1080.0 (982.5, 1122.4)	>0.9
MVPA (minutes)	84.7 (64.1, 103.9)	87.9 (70.7, 106.5)	83.3 (59.5, 102.1)	0.085
MVPA (%)	8.4 (6.4, 10.3)	8.7 (6.7, 10.5)	8.1 (6.1, 10.1)	0.051
SRT (minutes)	661.8 (584.4, 721.0)	655.3 (579.3, 709.2)	668.0 (591.2, 723.6)	0.180
SRT (%)	62.4 (58.8, 66.7)	62.0 (58.2, 66.2)	62.8 (59.3, 66.8)	0.187
Child follow-up daily physical activity	n = 426	n = 193	n = 233	
Total wear time (minutes)	1075.9 (948.3, 1123.0)	1080.7 (946.6, 1120.4)	1074.1 (953.1, 1125.7)	>0.9
MVPA (minutes)	73.6 (56.1, 96.0)	77.1 (59.6, 98.2)	71.7 (55.2, 93.4)	0.072
MVPA (%)	7.5 (5.6, 9.5)	7.8 (5.9, 9.7)	7.1 (5.4, 9.2)	0.081
SRT (minutes)	681.4 (600.3, 749.3)	671.6 (600.1, 745.4)	693.3 (602.5, 756.8)	0.344
SRT (%)	65.6 (60.9, 70.1)	64.7 (60.3, 70.0)	66.3 (61.5, 70.2)	0.130

high school), move status (mover or non-mover), intervention group (control or intervention), and parent ethnicity (Hispanic or non-Hispanic). Similar models were used to analyze follow-up mean daily SRT (replacing MVPA measures with SRT measures). Robust standard errors for the ordinary least squares estimator were used to allow for appropriate inferences from the obtained confidence intervals in the presence of non-normally distributed residuals. These analyses were repeated with parent physical activity data, and results are included in Appendices 2 and 3.

Attrition analysis was performed to ensure there were no significant differences between included and excluded participants on baseline analytic variables and on the outcome variables for those who had adequate follow-up accelerometry data using Wilcoxon rank-sum tests for continuous variables and chi-square tests for categorical variables. The baseline demographics and characteristics of the ineligible dyads (n = 184) were not significantly different from the analytic sample, and child mean daily MVPA and SRT were also not significantly different among those with data to compare. All analyses were completed in Stata 15.1, and statistical significance was defined using a two-sided test with $\alpha = 0.05$.

3. Results

The full trial recruited 610 dyads; dyads were excluded from this secondary analysis due to insufficient physical activity data (n = 132), baseline address outside of Davidson County (n = 8), incorrect baseline addresses (n = 4), and follow-up address outside of Davidson County (n = 40). 426 dyads met the criteria for inclusion (Fig. 1). Baseline demographics, family-level characteristics, and accelerometry data are summarized in Table 1, with comparisons between dyads that experienced residential mobility and those that did not. Overall, 92.0 percent (n = 392) of families were Hispanic, and 87.3 percent (n = 370) were enrolled in WIC or SNAP. Median (Q1, Q3) child age at baseline was 4.3 (3.6, 5.1) years old.

3.1. Residential mobility

During the trial, almost half of the analyzed dyads (45.3%, n = 193) moved to a new address within Davidson County, TN. Among dyads who moved, about half (n = 102/193) changed zip code, and the median (Q1, Q3) straight line distance between baseline and follow-up address was 2.39 (1.33, 4.66) mi. Some baseline differences existed between dyads who moved and those who did not. Dyads who moved had a lower rate of married parents (78.2% vs. 88.4%; p = 0.005), slightly younger parents (median age 31.2 vs. 32.8 years; p = 0.040), and more often had a female child (57.5% vs. 45.5%; p = 0.014) compared to dyads who did not move.

3.2. Neighborhood context

Baseline and follow-up neighborhood characteristics are summarized in Table 2 and separated by movers vs. non-movers. At baseline, the distribution of annual crimes was significantly higher among movers than non-movers (median of 90 vs. 77, respectively; p = 0.032); the distributions of other neighborhood variables did not differ significantly between groups at baseline or at follow-up. Both movers and non-

Table 2
Environmental characteristics at baseline and follow up by move status. Results presented as median (Q1, Q3) unless indicated otherwise. P-values are from Wilcoxon sign-rank tests comparing baseline to follow-up within each move status. Bolded values indicate significant differences between baseline and follow-up at the 0.05 level. Wilcoxon rank-sum tests were used to compare movers and non-movers at baseline and at follow-up. Asterisks indicate significant differences between movers and non-movers at the 0.05 level. Only the number of nearby crimes at baseline was significantly different between movers and non-movers (90 vs. 77; p = 0.032).

	Movers (n = 193)			Non-movers (n = 233)		
	Baseline	Follow-up	p-value	Baseline	Follow-up	p-value
Closest recreation site distance (mi)	0.79 (0.51, 1.24)	0.82 (0.44, 1.11)	0.061	0.75 (0.45, 1.19)	0.72 (0.41, 1.03)	**<0.001**
No. of crimes within 0.5 mi radius	90 (59, 168)*	80 (47, 126)	**<0.001**	77 (52, 149)*	74 (47, 128)	**<0.001**
Stray dogs/sq mi	36 (32, 57)	15 (15, 24)	**<0.001**	36 (32, 82)	18 (15, 24)	**<0.001**
Gini index	0.41 (0.38, 0.44)	0.38 (0.37, 0.42)	**0.032**	0.38 (0.36, 0.44)	0.39 (0.37, 0.42)	0.538

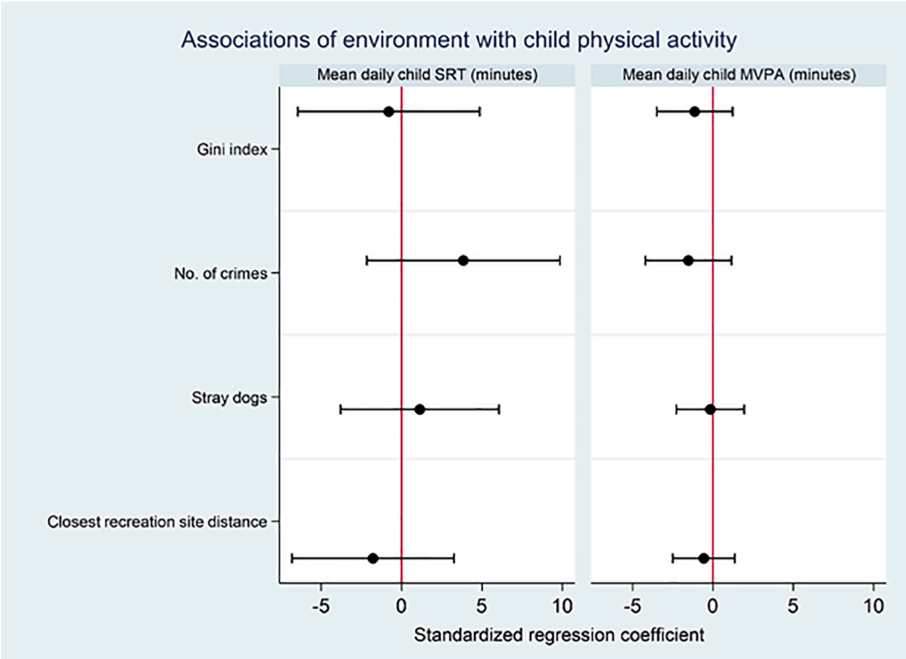

Fig. 2. Adjusted multivariable regression models evaluating associations between neighborhood context and child SRT/MVPA. Models controlled for baseline percent MVPA, follow-up accelerometer wear time (minutes), child age (years), child sex, child BMI (kg/m2), parent education, move status, intervention group, and parent ethnicity. These models failed to detect significant associations between neighborhood context variables and child physical activity. The standardized regression coefficients were nearly zero, with 95% confidence intervals crossing zero.

movers experienced significant positive change on some neighborhood measures. From baseline to follow-up, the distribution of the closest recreation site distance decreased significantly for non-movers (median of 0.75 to 0.72 mi; $p < 0.001$) but did not change significantly for movers (median of 0.79 to 0.82 mi; $p = 0.061$). The distribution of annual crimes improved significantly over time for both groups with the median decreasing from 77 to 74 among non-movers and 90 to 80 among movers ($p < 0.001$ for both). Annual stray dog exposure also decreased for both groups. The distributions of income inequality, as measured by the Gini index, were not significantly different between baseline and follow-up for non-movers. The distribution of income inequality was significantly lower at follow-up among movers, consistent with shifts in the median from 0.41 to 0.38 and indicating greater income equality at follow-up among movers ($p = 0.032$).

3.3. *Physical activity patterns*

Child median (Q1, Q3) daily accelerometer wear time at baseline and follow-up was 1080.2 (975.8, 1123.3) and 1075.9 (948.3, 1123.0) minutes/day, respectively, out of 1140 possible total minutes/day. At baseline, children spent a median of 84.7 (64.1, 103.9) minutes/day in MVPA and 661.8 (584.4, 721.0) minutes/day in SRT. At follow-up, children spent 73.6 (56.1, 96.0) minutes/day in MVPA and 65.6 (60.9, 70.1) minutes/day in SRT.

Bivariate Spearman correlations did not indicate any significant direct relationships between each neighborhood variable and child physical activity measures at baseline (not shown) or follow-up (Appendix Table 4).

3.4. *Adjusted analyses: Moving, neighborhood context and physical activity*

In models adjusting for both baseline demographics and contemporaneous neighborhood context, there were no statistically significant differences in child mean daily MVPA or SRT between movers or non-movers at baseline or follow-up (Fig. 2 for summary).

4. Discussion

In this sample of low-income, predominantly Hispanic families in a rapidly growing urban county, about half of the cohort experienced residential mobility; however, most did not move far (<3 mi away). Surprisingly, most measures of neighborhood context improved whether families moved or not, potentially influenced by Davidson County's investments in urban planning including increased parks and recreation centers over this time period. Moreover, young children in the sample were appropriately active at both baseline (84.7 min/day [64.1, 103.9]) and follow-up (73.6 min/day [56.1, 96.0]), exceeding national guidelines for MVPA in school-age children (60 min/day) at both data collection points. Although recommended amounts of preschool physical activity levels are less clear (with a goal of $\geq$ 3 h of total physical activity), by age 6, the recommendation is $\geq$ 60 min/day of MVPA (U.S., 2018). SRT increased between baseline and follow-up as the children aged, which is consistent with prior studies (Kwon et al., 2015). Within this context of general neighborhood improvement, no associations were found between objective measures of neighborhood context and MVPA or SRT in children.

To our knowledge, this study was unique in evaluating associations between objectively measured neighborhood context and MVPA and SRT in a longitudinal cohort of underserved young children. Although the study only lasted several years, significant environmental changes occurred over this period. These changes were likely due to rapid population growth in Nashville of approximately one percent per year, coupled with government-led initiatives to increase the number of parks and community centers within Davidson County (Harper, 2013). These concurrent changes in population density and recreation sites may reduce the positive benefits of additional recreation sites, as increased demand and traffic could potentially limit physical activity.

Future research on associations between health and objective neighborhood context would benefit from more rigorous environmental data collection. Cities that have successfully improved their built environment amid urban growth typically have strong support from the local government, institutionalized stewardship plans, data-driven planning policies, and diverse stakeholder involvement (Young, 2011; Cuthill, 2010). For cities to more effectively target future projects and improvement efforts, high quality data are critical. It would also be

Table A1
Data sources.

Neighborhood variable	Source	Level	Methodology
Closest recreation site distance (mi) Number of recreation sites within 0.5 mi network buffer	Nashville Open Data Portal, Nashville Metro Parks and Recreation website	Exact coordinates	-2016 dataset cleaned to include only public parks, greenways, public playgrounds, pools, and community centers -Baseline dataset generated by removing all sites established after 2011 -Recreation site entry points generated in ArcMap by intersection with road network -Measures generated through network analysis in ArcMap
Number of crimes within 0.5 mi linear buffer	Metro Nashville Police Department	Exact coordinates	-Datasets included all incidents reported to the MNPD annually -Only personal safety crimes (e.g., assault, burglary, harassment) were included, consistent with our prior work[14] - Incidents excluded if missing coordinates -Measure was highly associated with more sensitive kernel density estimate of crime by pairwise correlation (0.96, p<0.001)
Stray dogs per sq mi	Nashville Metro Animal Care and Control	Zip code	-Annual stray dog counts adjusted for zip code total land area
Income inequality (Gini index)	Census Population Estimates Program	Census tract	-Gini index connected with participant addresses by census tract

valuable to more rigorously evaluate the demographic differences we found between movers and non-movers (marriage rates, child gender, etc.) Finally, further analysis of the interrelatedness of parent and child physical activity within neighborhood context would be beneficial in guiding future interventions.

4.1. Study limitations and strengths

The challenges in this study are common among GIS studies relying on public data that may be incomplete and could influence associations. Neighborhood level data were collected at different levels of granularity based on availability. Recreation sites and crimes were tied to exact coordinates, while income inequality was measured at a census tract level and stray dogs at a zip code level (Appendix Table 1). Results could be influenced by the granularity of each measure. However, this approach is consistent with other studies examining the relationship between built environment and physical activity. Our work advances the ability to examine the relationship by providing objective, longitudinal physical activity data.

Baseline and follow-up data for participants were collected on a rolling basis and may not align precisely with neighborhood data. Due to the complexity of linking multiple data sources from different years to individual participants, and variability in the quality of data sources from year to year, we chose to anchor on when the study began in 2012, with follow-up data from 2016. Accelerometry cut-offs were based on values validated for preschool-age children but not older children; however, cut-offs are similar between age groups and this methodology was selected by NIH's Childhood Obesity Prevention and Treatment Research Consortium. Physical activity location was not captured through accelerometry data. The Gini coefficient solely tracks income inequality and does not include other socioeconomic variables that may

Table A2
Baseline and follow-up physical activity data for parents. Results presented as frequency (%) or median (Q1, Q3) and equality of groups was tested using a chi-square test or a Wilcoxon rank-sum test, respectively. Bolded values indicate significance at the 0.05 level.

Parent baseline daily physical activity	n = 397	n = 182	n = 215	
Total wear time (minutes)	1071.9 (966.7, 1127.0)	1082.9 (979.1, 1130.4)	1067.7 (962.5, 1126.3)	0.555
MVPA (minutes)	35.6 (22.6, 61.9)	35.6 (22.4, 61.9)	35.4 (22.7, 63.1)	0.727
MVPA (%)	3.4 (2.2, 5.9)	3.4 (2.2, 5.8)	3.5 (2.2, 6.3)	0.700
SRT (minutes)	485.9 (400.5, 556.7)	496.1 (408.0, 566.6)	479.1 (393.4, 554.9)	0.283
SRT (%)	46.1 (40.5, 52.4)	47.0 (41.0, 53.3)	45.5 (39.7, 51.8)	0.122
Parent follow-up daily physical activity	n = 398	n = 175	n = 223	
Total wear time (minutes)	1043.2 (898.4, 1106.6)	1029.7 (910.6, 1103.4)	1052.9 (882.0, 1117.8)	0.826
MVPA (minutes)	42.0 (24.1, 71.4)	37.9 (23.6, 65.7)	44.0 (24.6, 75.9)	0.359
MVPA (%)	4.1 (2.6, 7.2)	3.8 (2.5, 6.9)	4.2 (2.6, 7.3)	0.340
SRT (minutes)	460.1 (371.0, 537.6)	474.7 (379.0, 550.1)	447.3 (363.7, 525.7)	0.104
SRT (%)	46.1 (38.5, 52.6)	46.6 (40.1, 53.3)	44.9 (37.5, 52.0)	0.104

Table A3
Bivariate Spearman correlations between environmental variables and parent physical activity.

	Parent daily average SRT (minutes)		Parent daily average MVPA (minutes)	
	Coefficient	p-value	Coefficient	p-value
Closest recreation site distance (mi)	0.038	0.447	−0.068	0.174
No. of crimes within 0.5 mi radius	0.024	0.633	−0.044	0.380
Stray dogs/sq mi	−0.030	0.546	0.094	0.061
Gini index	−0.004	0.943	0.090	0.074

Table A4
Bivariate Spearman correlations between environmental variables and child physical activity.

	Child daily average SRT (minutes)		Child daily average MVPA (minutes)	
	Coefficient	p-value	Coefficient	p-value
Closest recreation site distance (mi)	−0.015	0.753	−0.022	0.649
No. of crimes within 0.5 mi radius	−0.013	0.790	−0.071	0.143
Stray dogs/sq mi	0.011	0.819	0.026	0.596
Gini index	0.006	0.901	0.010	0.842

impact physical activity. Finally, it was not possible to differentiate between sedentary time and sleep. However, accelerometer data collected 00:00–04:59 was excluded to reduce the contribution of sleep to the SRT measure.

This study had several strengths. The study used objective data for both the explanatory variables (neighborhood context) as well as the outcomes (MVPA and SRT), whereas many built environment studies employ perception-based measures. This allowed for objective longitudinal assessments of a highly-phenotyped cohort of 426 parent–child pairs from underserved, largely Hispanic families, a group at high risk for insufficient physical activity and obesity (Hales et al., 2017; Brewer and Kimbro, 2014; Sharifi et al., 2016). While built environment is one factor that influences physical activity in underserved populations, other neighborhood factors that may impact interactions with the built environment were evaluated, including safety (e.g. crime and stray dogs) and socioeconomic factors (e.g. economic inequality) (Johnson et al., 2019).

5. Conclusions

In this longitudinal study in a rapidly growing county, measures of neighborhood context (distance to the closest recreation site, annual crime, annual stray dogs, and income inequality) generally improved for the underserved families in the cohort, regardless of whether they moved. Although 45.3% of families moved during the study, the median move distance was small (<3 miles). Within this context, regression analyses did not reveal a statistically significant effect of neighborhood context on either child or parent MVPA or SRT. Continued research in this area is critical, especially as cities in the United States continue to undergo rapid infrastructural and demographic changes.

6. Availability of data and materials

The GROW trial data used during the current study are housed in BIOLINCC, however address data will not be publicly available. Environment-level data are available by request from the associated government agencies (Appendix Table 1).

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8. Authors' contributions

SR, WH, ES, and SB conceptualized this study and developed the methods and analysis plan. SR completed the GIS analysis and some parts of the statistical analysis and was a major contributor in writing the manuscript. ES completed the statistical analyses and was a major contributor in writing the manuscript. SB conceptualized and conducted the original GROW trial. All authors participated in data interpretation. WH substantially revised the manuscript. All authors read and approved the final manuscript.

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

Tables A1–4

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