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Disparity in Built Environment and Its Impacts on Youths' Physical Activity Behaviors During COVID-19 Pandemic Restrictions

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Abstract

Objectives Guided by the social ecological model, this study aimed to examine the relations of built environments (i.e., walking/cycling infrastructure, recreation facilities, neighborhood safety/crime), youth's transition abilities, and changes of youth's physical activity (PA) and play behaviors due to COVID-19-based restrictions. Ethnic and socioeconomic status (SES) disparities were also examined on studies variables during the COVID-19 restrictions.

Method A cross-sectional research design was used to assess an anonymous online survey completed by US parents/guardians. The final sample had 1324 children and adolescents ($Mean_{age} = 9.75$; $SD = 3.95$; 51.3% girls), and 35.5% the families were of upper socioeconomic class (income > $150,000). Parents reported the perceived built environment and neighborhood safety, child's PA and play behaviors during COVID-19 pandemic shelter-in-place restrictions.

Results Youths who had access to safe built environment were more active and played more outdoor/indoor ($p < .01$). It was found playing behavior in yard and neighborhood were significantly increased, but community-based play behavior was significantly reduced during COVID-19 restrictions. The SEM analysis ($\chi^2/df = 236.04/54$; $CFI = .966$) supported indirect and direct effects of neighborhood safety on PA changes during COVID-19 restrictions, and the youth's ability to respond to COVID-19 restrictions served as a full mediator. Low-SES and Hispanic minority youth reported significantly less safety to walking or playing in their neighborhoods than their middle-/high-SES non-Hispanic peers ($p < .001$). Regardless of ethnicity, the magnitude of the reduction of MVPA was significantly higher among low-SES groups than that of the high- and middle-SES groups ($p < .001$).

Conclusions These findings demonstrate a need to tailor programs and policies to help high-risk groups (e.g., low SES) stay active, healthy, and resilient during and after the COVID-19 pandemic.

Keywords Physical activity · Play behavior · Ethnic/racial disparities · Built environments · Socioeconomic status

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The health benefits of regular physical activity (PA) are well documented for youth. Currently, research reports that more than half of US children fail to meet the 60-min moderate-to-vigorous physical activity (MVPA) guidelines, and PA consistently declines from childhood to adolescence [1–3]. Due to public health measures during the coronavirus disease 2019 (COVID-19) pandemic, unfortunately, people of all ages are experiencing an extraordinary challenge, and their daily PA behaviors/patterns have been altered in response to the "social distancing" and "shelter in place" mandates [4–6]. Behavioral and environmental changes due to the COVID-19 pandemic have been observed in the US pediatric population [6–8], however, large data-based investigations in PA disparities are lacking. During the early phase of the COVID-19 pandemic, one study [9] conducted in Canada reported that children with congenital heart disease (CHD; n = 109) had a decline of 21–24% of their overall daily step-counts after implementing social distancing and suspension of K-12 schools (March 17, 2020). Given the strong link between PA and major non-communicable diseases [10], assessing disparities in PA and their potential social ecological determinants during this global pandemic is essential from public health perspectives in order to guide policy development for future crises.

Healthy People 2030 [11, 12] and the Institute of Medicine [13] identified the importance of the social ecological model related to PA in health promotion and disease prevention. In this model, individuals, built environments, and policy factors have been identified as important determinants of PA behaviors [14]. Over the past decades, emerging research and political interest have been focused on the role of built environments in supporting PA behaviors [14–17]. Findings from quantitative studies and recent reviews suggest that neighborhood built environments including presence of sidewalk/cycling paths, availability of park and recreation resources, and transportation infrastructure are consistently associated with PA and in particular with leisure walking [15, 17–19]. Very limited evidence is available to investigate the relation of environmental health disparities and their association with increased risk of physical inactivity, as well as socioeconomic status (SES) and racial/ethnic disparities [18, 20, 21]. It was documented that parks provide both space and facilities to support PA and are often underutilized in low-income neighborhoods [22]. Low-SES and high-minority groups were less likely to have accessible facilities compared to high-SES and Non-Hispanic groups [23]. It was also noted that increasing recreation facilities for free to at low costs [24, 25] can play a critical role in disease prevention, especially in the disadvantaged minority communities.

As social ecological models particularly emphasize the environmental attributes and context-specific PA should be conceptually matched, it is urgent to retrospectively assess PA behavioral changes (intensity levels and types) among children and adolescents during the COVID-19 pandemic and assess how social ecological factors may correlate with these changes [8, 26, 27]. Attention to health disparities is increasing in public health and epidemiological research [27, 28]. One most recent study reported social and economic status impact on neighborhood walkability across 500 US cities; that is, low-income majority Black and Latino neighborhoods had lower walk scores than low-income majority White neighborhoods [29]. Thus, it was vital to explore how disparities in built environments contribute to disparities in behavioral changes during COVID-19 pandemic. It was noted that positive attributes of the built environment such as walkable, safe, and healthy communities, are associated with good population health and behaviors [20]. Gordon-Larson and colleagues [23] also reported that inequitable PA facilities distribution is significantly associated with subsequent disparities in obesity-related behaviors, and ethnic minorities are at the higher risk for inequitable accessibility to recreational and PA facilities.

As one of the first US pediatric population large scale studies during the middle of the COVID-19 global pandemic (April–July 2020), this study aimed to produce comprehensive estimates of youth's PA behaviors, and provide insights for practices and policies by identifying potential environmental determinants of reduced PA during global pandemic. Guided by the social ecological model [14], this study aimed to examine the relations of built environments (i.e., walking/cycling infrastructure, recreation facilities, neighborhood safety/crime) and youth's changes of PA participation and play behaviors during COVID-19 restrictions. This period included when restrictions (i.e., shelter-in-place, stay home, school and recreation program closings) were in place. Specifically, the direct and indirect effects of the built environment on leisure-time PA (i.e., LPA, MPA, and VPA) and play behaviors (i.e., PA in yard, PA in community, PA in neighborhood, indoor PA) were investigated using structural equation modeling, respectively. The second purpose of this study was to examine how ethnic and SES differences impacted the built environment, youth's responses to COVID-19-based restrictions, and changes of PA participation and play behaviors during COVID-19 among youth in the USA.

Methods

Participants

There were 1394 children and adolescents aged 3–17 years old with survey data for the study. One thousand three hundred and twenty-four (1324) out of 1394 children and adolescents (51.3% girls, $Mean_{age} = 9.75$; SD = 3.95) became the final sample (70 missed more than half of the survey items and were removed) and were included in the data analysis. Household income was used to categorize the three SES groups: Low SES (< $50,000; 6.6%), middle SES ($50,000-$150,000; 53.1%) and high SES (> $150,000; 32.6%). The races consisted of White (83.2%), Black (4.8%), Asian (3%), and other races (9.9%), and ethnicity (12.4% Hispanic), respectively.

Measurements

Demographics Age, sex, race, ethnicity (non-Hispanic vs. Hispanic), parents' highest education, household income, house type, and home location (urban, suburban, vs. rural) were collected using an online survey (Research Electronic Data Capture [REDCap]).

Child Ability to Respond COVID-19 Restrictions The child's ability to transition during the COVID-19 restrictions, social distancing and sheltering-in-place, was measured with two items: "… your child's ability to transition to social distancing since the pandemic started" and "… your child's ability to transition to shelter-in-place since the pandemic started." Parents were asked to respond based on a 10-point Likert scale ranging from 1 (*extremely easy*) to 10 (*extremely hard*). The scale showed a high reliability in this study (Cronbach's alpha = 0.915).

Built Environment A modified 8-item Physical Activity Neighborhood Environment Scale (PANES) [17] was used to assess perceived built environment at the neighborhood level including walking/cycling infrastructure (4 items), recreation facilities (2 items), and neighborhood safety (2 items). Responses were based on a 4-point Likert scale ranging from 0 (*strongly disagree*) to 4 (*strongly agree*). The average score for each subcategory was calculated ranging from 0 to 4, with the higher scores representing a greater supportive built environment toward PA. The reliability and the validity of the modified PANES were tested by the confirmatory factor analysis (CFA).

Intensity Levels of PA The Godin-Shephard Leisure-Time Physical Activity Scale (LTPA) [30] was used to capture the intensity level of PA including light PA [LPA], moderate PA [MPA], and vigorous VPA [VPA] before and during COVID-19. The weighted leisure-time score index (LSI) was obtained using the following LSI formula: (frequency of light × 3) + (frequency of moderate × 5) + (frequency of vigorous × 9). The individuals were classified into two categories: individuals reporting moderate-to-strenuous LSI ≥ 24 are classified as active, and individuals reporting moderate-to-strenuous LSI ≤ 23 are classified as insufficiently active (estimated energy expenditure < 14 kcal/kg/week) [30]. The participants completed the LTPA scale twice to recall the number of times they engage in mild, moderate, and strenuous LTPA bouts of at least 15 min duration in a typical week before and during the COVID-19 restrictions, respectively. The physical activity changes of LPA, MPA, and VPA were calculated by using the pre-COVID-19 score subtracts the during-COVID-19 score and used in the data analysis.

Play Behaviors Youth play behaviors during COVID-19 were measured with a 7-item scale including outdoor PA (in yard, neighborhood, and community) and indoor PA (child-led PA, parent-led PA, and online PA). Parents were asked to recall their child's participation in different types of physical activities in the past seven days and rate how much had changed during the shelter-in-place and school and recreation activity program closings compared to before the pandemic. Responses were based on a 4-point Likert scale including *1* (*Does not do this activity*), *2 (Less than before), 3 (About the same),* and *4* (*More than before*). The sample items for outdoor and indoor PA were: outdoor activities in your neighborhood—walking, biking, or jogging; and indoor child-led activities—yoga, stretching, weightlifting, or dancing. The average score for each subcategory was calculated for indoor (3 items) and outdoor PA (4 items), as well as for each type of play behavior (Cronbach's alpha = 0.703).

Data Collection and Procedure

A cross-sectional research design was applied in this study. The study focused in the state of Texas with national distribution through social media (Twitter/Facebook) and snowball sampling, where participants were encouraged to share the survey link. This study was approved by the UT Southwestern Medical School Institutional Review Board (IRB). Flyers were emailed to schools, youth groups (sport teams, scouting groups, etc.), support groups for parents of children with special needs, cultural/religious organizations, and personal and professional contacts of the study team. REDCap (Research Electronic Data Capture) was utilized to collect the online survey data, and it is a web-based software platform designed to support data capture for research studies [31, 32]. The survey was active between April 4 and June 27, 2020, while most US areas were under government-mandated activity restriction, including social distancing, stay-at-home, and/or shelter-in-place orders. A waiver of written informed consent was obtained, and participants provided electronic consent with survey initiation.

Data Analysis

The data analysis was processed using SPSS 26 and AMOS Version 26 (IBM Corp, Armonk, NY, USA). To test the association among this study's variables, bivariate correlation analysis was performed. Then, structural equitation modeling (SEM; AMOS 26) was implemented to further test the direct and indirect relations of the built environment and youth's ability to respond COVID-19 restrictions with changes of PA intensity and type of activity during COVID-19 pandemic restrictions. To examine the construct validity and internal reliability of built environment scale, a confirmatory factor analysis (CFA) was conducted to test how well the measured variables represented the number of sub-constructs before completing the SEM model. Maximum likelihood estimates were used for all SEM analyses.

Finally, the multivariate analysis of covariance (MANCOVA) analysis was conducted to examine ethnic (Hispanic vs. non-Hispanic) and SES (low SES vs. middle SES vs. high SES) effects on the built environment, and children's ability to respond to COVID-19 restrictions; and changes of PA participation and play behavior (play in yard, neighborhood, and community), controlled for demographics variables (i.e., gender, age, house type, and location), respectively.

Furthermore, one-sample *t* test was conducted for testing of sample means on play behaviors comparing the mean of the sample to a pre-specified value and tests for a deviation from that value. Specifically, the sample responses toward play behavior changes (i.e., in yard, neighborhood, community, indoor) during COVID-19 have four responses and the average response value is three (3 = *same as before)* and we compared the "*less than before*" or "*more than before*" responses to this value. An alpha level of 0.05 was used for all statistical analyses, Bonferroni corrected to 0.0125.

Results

Sample and Socioeconomic Characteristics

Overall, participants-initiated surveys for a total of 1394 US children ages 3–17 years, however 70 surveys (more than half of the survey items were missed) were excluded in the data analysis. The final sample had 1324 children and adolescents (674 girls), and majority of them lived in the urban/city areas (92.8%), single-family houses (90.6%), and 32.6% of the families were considered upper class (income > $150,000) (Table 1).

Table 1 Descriptive statistics of the study participants ($N = 1324$)

Variables	N (%)	Mean (SD)
Sex		
Girls	674 (50.9%)	
Boys	639 (48.3%)	
Race		
White	83.2%	
Black	4.8%	
Asian	3.0%	
Native American or American Indian	0.6%	
Native Hawaiian or Pacific Islander	1.6%	
Multi-race	6.7%	
Ethnicity		
Hispanic/Latino	164 (12.4%)	
Non-Hispanic/Latino	1128 (85.2%)	
House types		
Single family	1200 (90.6%)	
Mobile home	13 (1%)	
Apartment/condo	61 (4.6%)	
Townhouse/duplex or low	48 (3.6%)	
House Holder Income		
< $50,000	80 (6.6%)	
$50,000–$150,000	702 (53.1%)	
> $ 150,000	431 (32.6%)	
Geography		
Rural	28 (2.1%)	
Suburban	67 (5.1%)	
Urban/City	1227 (92.8%)	

N = Number of participants. *M* = Mean; *SD* = Standard deviation

Direct and Indirect Relations of Built Environment on PA and Play Behavior Changes

The correlation analysis (Table 2) indicates that all intensity levels of PA changes were significantly correlated with indoor and outdoor play behaviors (*rs* range from -0.13 to -0.32; $p < 0.01$); that is, youth who engaged in more outdoor or indoor play behaviors were more likely to participate in more LPA and/or MVPA in COVID-19 restrictions (lower PA change score). It was found youth's ability to respond to COVID-19 restrictions (social distancing and shelter-in-place) were correlated with all intensity levels of PA ($p < 0.01$); and negatively associated with play behavior in yard, neighborhood, and indoor ($p < 0.01$), but not related to play behavior in the community. Youth who had better abilities to transition in response to COVID-19 restrictions were more active and engaged in more play behaviors ($p < 0.01$) than those who were less able to adapt. The perceived built environment factors including walking/cycling

Table 2 Correlation analysis among study variables ($N = 1324$)

Variables	1	2	3	4	5	6	7	8	9	10	11	12
1. Social Distancing	-											
2. Shelter-in-place	0.84**	-										
3.Walking/Cycling	-0.08**	-0.08**	-									
4. Recreation Facilities	-0.07**	-0.02	0.48**	-								
5. Neighborhood Safety	-0.11**	-0.09**	0.15**	0.27**	-							
6. LPA Changes	0.11**	0.12**	-0.05	-0.08**	-0.06*	-						
7. MPA Changes	0.11**	0.11**	-0.01	-0.01	-0.06*	0.37**	-					
8. VPA Changes	0.11**	0.11**	-0.06*	-0.02	-0.03	0.27**	0.47**	-				
9. Play in Yard	-0.08**	-0.05	0.03	0.11**	0.14**	-0.22**	-0.23**	-0.18**	-			
10. Play in Neighborhood	-0.07**	-0.03	0.15**	0.16**	0.19**	-0.32**	-0.28**	-0.21**	0.40**	-		
11. Play in Community	-0.04	-0.02	0.09**	0.07**	0.07*	-0.16**	-0.20**	-0.14**	0.19**	0.43**	-	
12. Indoor Play	-0.06**	-0.03	0.03	0.01	-0.04	-0.13**	-0.13**	-0.18**	0.26**	0.16**	0.15**	-

PA = Physical activity; LPA = light physical activity; MPA = moderate physical activity; VPA = vigorous physical activity

The values of the LPA, MPA, and VPA were mean changes during COVID-19 restrictions by using the pre-COVID-19 score subtracts the during-COVID-19 score and the higher/positive change scores indicated less active of the individual during COVID-19. * $p < .05$. ** $p < .01$

infrastructure, recreation facilities, and neighborhood safety, were found to be associated with all outdoor play behaviors (*rs* range from 0.07 to 0.19; $p < 0.05$), but not indoor PA. The results also indicated that neighborhood safety was significantly related to LPA and MPA ($p < 0.01$); only the walking/cycling infrastructure was significantly associated with VPA ($p < 0.01$; Table 2).

Then, the direct and indirect relations of the perceived built environment (i.e., walking/cycling infrastructure, recreation facilities, and neighborhood safety) and youth's ability to transition to respond to COVID-19 restrictions on the PA and player behavior changes during pandemic were conducted using two SEM models. Before the model testing, the CFA model was conducted to test the reliability and validity of the built environment scale. As displayed in Table 3, goodness-of-fit indices suggested that CFA model[a] did not fit the data well ($\chi^2/df = 894.84/17$, $p = 0.001$). Using the modification indices, two covariance between measurement errors of the items of built environment were added (items 3 and 4: see CFA[b]). The CFA model suggested a validity measurement model for the built environment scale (8 items with three sub-constructs) after the error covariance were specified in CFA[b] model (Table 3), and the goodness-of-fitness indices (χ^2/df = 171.55/16, RMSEA = 0.08[90% CI = 0.072, 0.095], CFI = 0.96; IFI = 0.96; NFI = 0.95) supported a model fit the data well (Table 3).

The first SEM model (see Fig. 1) examined the potential direct and indirect effects of built environment on youth's ability to respond to COVID-19 restrictions and their LPA, MPA, and VPA changes. The goodness-of-fit indices suggested a well-fitting model (χ^2/df = 236.04/54; NFI = 0.957; IFI = 0.966; CFI = 0.966; RMSEA = 0.050; 90% CI [0.044, 0.057]). The standardized path coefficient of the model supports that neighborhood safety emerged as the significant predictor of youth's ability to respond COVID-19 restrictions ($\beta = -0.14$, $p < 0.001$; direct effect) and their PA intensity changes ($\beta = 0.11$, $p < 0.05$; direct effect), respectively. However, the direct

Table 3 Goodness-of-fit indices for CFA and structural models

Model	χ^2/df	*p*	NFI	IFI	TLI	CFI	RMSEA	90%CI	$\Delta\chi^2$/df
CFA[a]	894.84/17	.000	.743	.747	.461	.746	.193	[.182, .203]	
CFA[b]	171.55/16	.000	.951	.955	.899	.955	.084	[.072, .095]	
a vs. b									723.29/1*
SEM Model 1	236.04/54	.000	.957	.966	.943	.966	.050	[.044, .057]	
SEM Model 2	318.71/66	.000	.942	.954	.926	.953	.054	[.048, .060]	

[a] The original CFA model of built environment; [b] The CFA model with one added error covariance between item 3 and 4

CFA = Confirmatory factor analysis (CFA); NFI = Normed fit index; IFI = Incremental fit index; TLI = Tucker–Lewis index; CFI = Comparative fit index; RMSEA = Root mean squared error of approximation; CI = Confidence interval; df = Degree freedom; SEM = Structural equating modeling. SEM Model 1 for PA intensity changes; SEM Model 2 for types of PA changes. * $p < .05$. ** $p < .01$

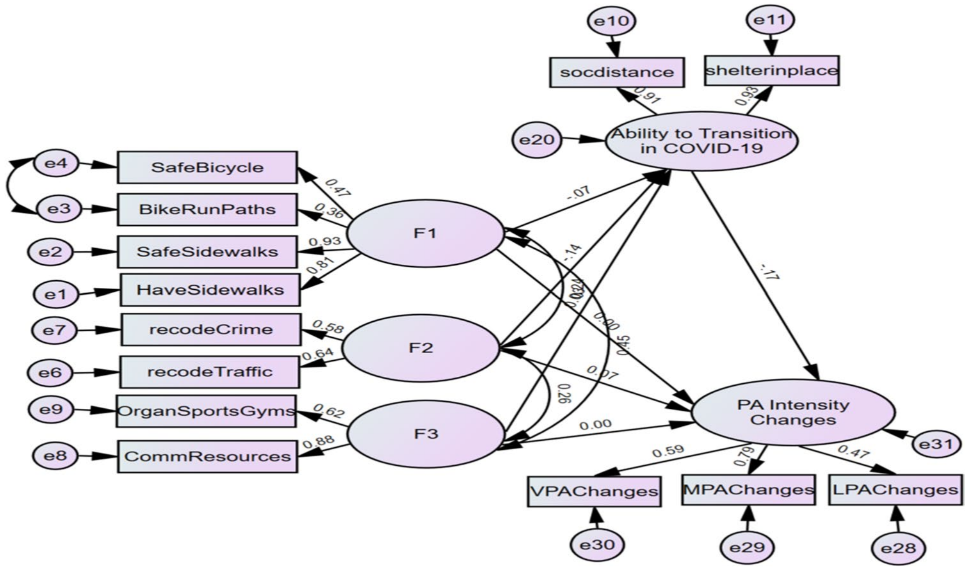

Fig. 1 Direct and indirect effects of built environment on physical activity during COVID-19 restrictions. *Note:* PA = physical activity; LPA = light physical activity; MPA = moderate physical activity; VPA = vigorous physical activity. * $p<.05$. ** $p<.01$

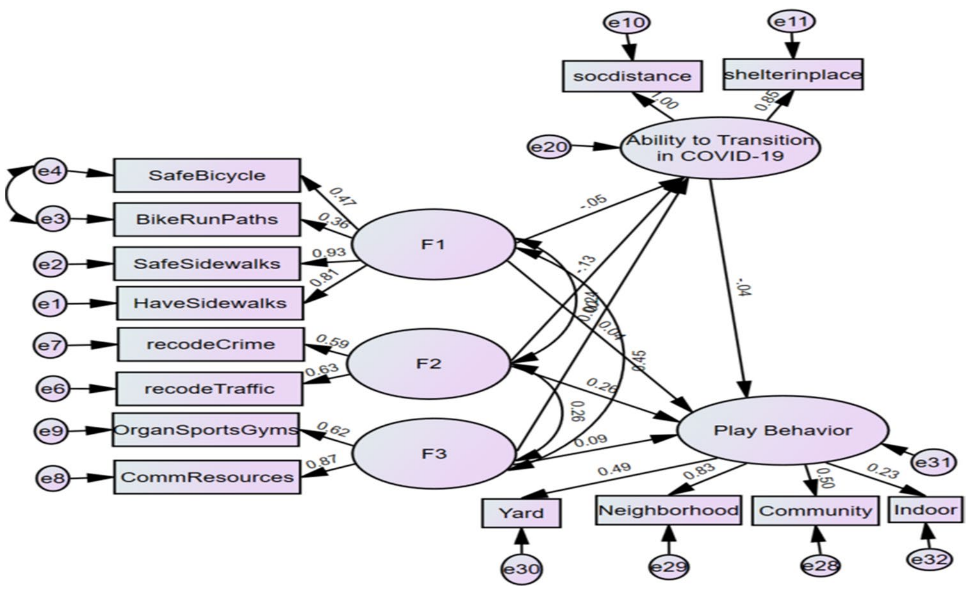

Fig. 2 Direct and indirect effect of built environment on play behavior during COVID-19 restrictions. *Note:* PA = physical activity; LPA = light physical activity; MPA = moderate physical activity; VPA = vigorous physical activity. * $p<.05$. ** $p<.01$

effects from built environment to changes of PA intensity became nonsignificant (from $\beta = -0.11$ to $\beta = -0.07$) after adding the direct path between youth's ability to respond to COVID-19 restrictions and changes of PA intensity ($\beta = -0.17$, $p < 0.001$; see Fig. 2). The variance explained in the dependent variables by the model was 4%. The indirect effect of built environment on changes of PA intensity through the youth's ability to respond to COVID-19 restrictions was supported [33], suggesting that youth's ability to respond to COVID-19 restrictions served as a full mediator in this relationship. That is, youth who live in supportive neighborhood environments (less traffic and crime rates) were more likely to be active during the COVID-19 pandemic restriction period, whereas youth who had trouble responding to the COVID-19 restrictions (e.g., social distancing and sheltering-in-place) may eliminate the direct positive effects.

The second SEM model (see Fig. 2) examined the potential direct and indirect effects of built environment on youth's ability to respond to COVID-19 restrictions and changes in play behaviors. The goodness-of-fit indices suggested a well-fitting model (χ^2/df = 318/66; NFI = 0.942; IFI = 0.954; CFI = 0.953; RMSEA = 0.054; 90% CI [0.048, 0.060]). This model supports that neighborhood safety was the significant predictor of youth's ability to respond COVID-19 restrictions ($\beta = -0.14$, $p < 0.001$; direct effect) and play behavior ($\beta = 0.27$, $p < 0.001$; direct effect), respectively. The direct effects from built environment to play behavior remained significant (from $\beta = 0.27$ to $\beta = 0.26$, $p < 0.001$) after adding the direct path between youth's ability to respond to COVID-19 restrictions and play behavior ($\beta = -0.04$, $p = 0.32$; see Fig. 2). The model supports that neighborhood safety explained all the variance ($R^2 = 10\%$, $p < 0.001$) on play behavior changes during the pandemic, regardless of how well youth made transitions in response to the COVID-19 restrictions, which was negatively influenced by the built environment.

PA and Play Behavior Changes During Pandemic in Overall Sample

In the total sample, a decline in PA at all intensity levels was observed during the COVID-19 pandemic shelter-in-place restrictions. Paired sample *t* test indicated that the MVPA during COVID-19 pandemic was significantly reduced in the overall sample compared to the MVPA before the COVID-19 (46.68 vs. 34.71; 95% CI [10.32, 13.59]; Cohen's d = 0.40; $p < 0.001$); however, the reduction of LPA did not reach significant level (9.96 vs. 9.93; 95% CI [-0.37, 0.42]; $p = 0.889$). According to the weighted leisure-time score index (LSI), 83.7% youth were classified as active (LSI ≥ 24) before the COVID-19 restrictions, but the active proportion was significantly reduced to 63.3% during this period (95% CI [0.17, 0.23]; Cohen's d = 0.38; $p < 0.001$).

The one-sample *t* test (test value set as 3 = *same as before*) indicated that play behavior in yard and neighborhood were significant increased during the COVID-19 pandemic restrictions. As shown in Fig. 3, there were 62.7% and 56.5% of participants reported playing in their yards (3.33/4.00) and neighborhoods (3.22/4.00) were *"More than before*" during COVID-19 restrictions, respectively. However, community-based play behavior (2.46/4.00) was significantly reduced in this sample during the pandemic restriction period, and 32.8% of the participants reported their engagement in community-based play behavior was "*less than before*."

Ethnic and SES Effects on PA and Play Behaviors

After controlling for all the demographic covariates (age, gender, house type, and location), there were significant SES effects (Wilks' Lambda = 0.959, $F_{(14, 1970)} = 2.95$, $p < 0.01$, $\eta^2 = 0.021$) on PA intensity and play behavior changes during the COVID-19 pandemic restrictions, yet ethnicity did not reach significance in this model [Wilks' Lambda = 0.994, $F_{(3, 1142)} = 2.175$, $p = 0.09$, $\eta^2 = 0.01$]). Regardless of ethnicity, the magnitude of the reduction of MVPA was significantly higher among the low-SES group than that of in the high- and middle-SES groups according to the mean change scores between pre-COVID-19 and during COVID-19. Specifically, three SES groups showed significant reduced MPA (9.68 low SES vs. 3.20 middle SES vs. 3.44 high SES; $F_{(2, 1001)} = 4.71$, $p < 0.01$), and VPA (11.90 low SES vs. 7.09 middle SES vs. 8.80 high SES; $F_{(2, 1001)} = 1.35$, $p < 0.01$) during pandemic restrictions. Only the low-SES group showed a reduced LPA participation (1.94 low SES vs. 0.25 middle SES); whereas the middle- and high-SES groups showed a slightly increased LPA during pandemic (-0.17 middle SES vs. -0.48 high SES).

Regardless of ethnicity, both high-SES and middle-SES groups engaged in more yard-based ($F_{(2, 1001)} = 6.77$, $p < 0.001$) and neighborhood-based play behaviors (*F*

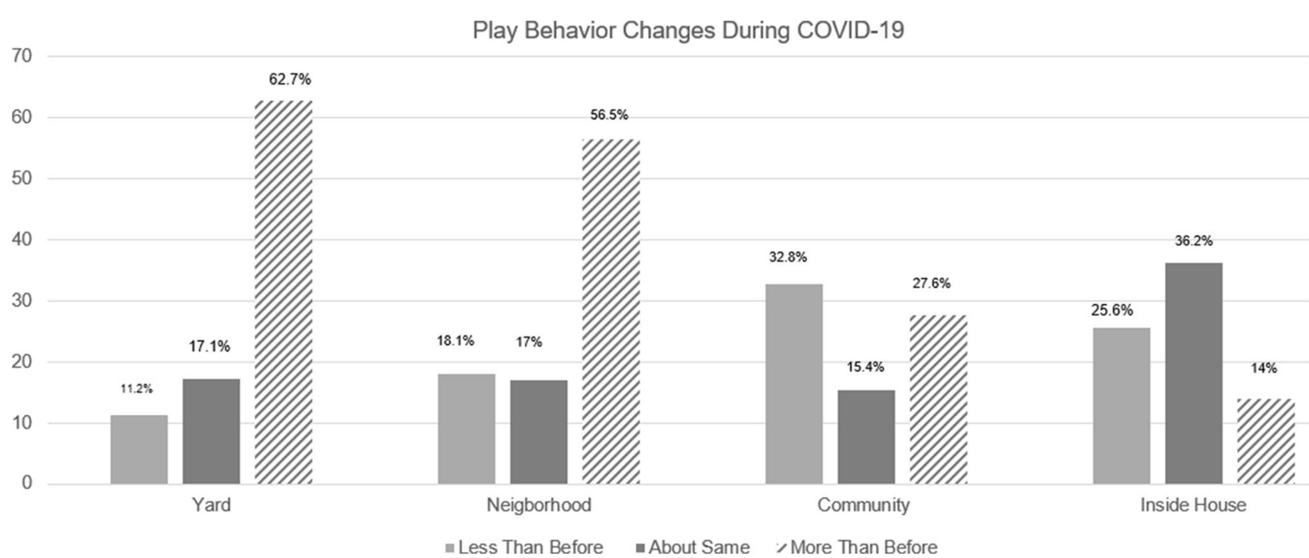

Fig. 3 Types of PA changes during COVID-19 restrictions. *Note.* PA = physical activity; *T* test results: Play behavior in yard: t (1121) = 11.26, $p < .001$; Play behavior in neighborhood: t (1119) = 7.10, $p < .001$; Play behavior in community: t (1119) = -15.81, p < .001; and Play behavior inside house: t (1118) = -10.31, $p < .001$

Table 4 Ethnic and SES disparities in physical activity and play behavior during COVID-19 restrictions

Variables	Ethnicity Hispanic	Non-Hispanic	Low SES	Socioeconomic Middle SES	High SES
Physical Activity					
LPA Changes	0.22 (7.95)	-0.21 (6.98)	1.94 (7.15)**	-0.17 (6.77)**	-0.48 (7.58)**
MPA Changes	5.30 (13.12)	3.44 (12.53)	9.68 (13.64)**	3.20 (12.44)**	3.44 (12.49)**
VPA Changes	8.19 (23.53)	7.98 (21.61)	11.90 (21.54)	7.09 (21.22)	8.80 (22.85)
Play Behavior					
Play in Yard	3.19 (1.09)	3.39 (0.96)	2.87 (1.03)**	3.43 (0.93)**	3.34 (1.02)**
Play in Neighborhood	3.04 (1.11)	3.25 (0.99)	2.48 (1.11)**	3.20 (1.01)**	3.39 (0.96)**
Play in Community	2.34 (1.12)	2.50 (1.12)	2.05 (1.08)*	2.47 (1.09)*	2.56 (1.15)*
Indoor Play	2.59 (0.95)	2.73 (0.96)	2.39 (0.98)	2.73 (0.96)	2.73 (0.95)

Covariates were controlled including sex, age, house type, and location. SES = socioeconomic status; LPA = light physical activity; MPA = moderate physical activity; VPA = vigorous physical activity. Physical activity changes were calculated by using the pre-COVID-19 score subtracts the during-COVID-19 score and the higher/positive change scores indicated less active of the individual during COVID-19. Play behavior changes were based on the survey responses on a 4-point Likert scale including *1* (*Does not do this activity*), *2 (Less than before), 3 (About the same),* and *4* (*More than before*)

[*] indicates the significant SES or ethnic differences. * *p < .05*. ** *p < .01*

$_{(2, 1001)} = 14.53$, $p < 0.001$) than that of low-SES group. All three SES groups reported less engagement in community-based play behavior during COVID-19 (2.05 low SES vs. 2.47 middle SES vs. 2.56 high SES; $F_{(2, 1001)} = 3.21$, $p < 0.05$). There were no significant ethnic and SES effects on engagement of indoor play behaviors during COVID-19 in this study (see Table 4).

Ethnic and SES Effects on Built Environment and Youth's Ability to Respond to COVID-19 Restrictions

The MANCOVA yielded significant main effects for ethnicity [Wilks' Lambda = 0.966, $F_{(, 971)} = 6.85$, $p < 0.01$, $\eta^2 = 0.034$] and SES [Wilks' Lambda = 0.908, $F_{(10, 1942)} = 9.61$, $p < 0.001$, $\eta^2 = 0.047$] on built environment (i.e., walking/cycling infrastructure, recreation facilities, and neighborhood safety) after controlling for all covariates, and a significant interaction between ethnicity and SES was found [Wilks' Lambda = 0.968, $F_{(10, 1942)} = 3.19$, $p < 0.001$, $\eta^2 = 0.016$]. No significant ethnic and SES effects were found on the youth's ability to respond to COVID-19 restrictions in this sample. As shown in Fig. 4, low-SES and Hispanic youth experienced significantly less safety to walking or playing in the neighborhood than their middle/high non-Hispanic peers ($F_{(1, 985)} = 31.47$, $p < 0.001$, $\eta^2 = 0.031$). It was found that the low-SES group showed significantly lower values on all built environment indicators including walking/cycling infrastructure ($F_{(2, 985)} = 16.12$, $p < 0.001$, $\eta^2 = 0.032$), recreation facilities ($F_{(2, 985)} = 17.43$, $p < 0.001$, $\eta^2 = 0.035$), and neighborhood safety ($F_{(2, 985)} = 35.09$, $p < 0.001$, $\eta^2 = 0.067$), regardless of their ethnicity.

Discussion

Built environmental factors have been suggested to play a major role in PA and other obesity-related behaviors. However, there is no national research on the relationship between disparities in built environments (e.g., neighborhood safety/crime, access to recreational facilities) and their impact on PA and player behavior changes in US youth during the COVID-19 pandemic restrictions. The findings of this study showed that during COVID-19, a high proportion of youth reduced their MVPA (from 83.7% to 63.3%) despite increases in their family use of community amenities such as parks, trails, and playgrounds. PA intensity levels decreased in children and worsened with age during COVID-19 pandemic [6]. With the closure of schools, sports programs and clubs, and recreation centers in most US communities during the COVID-19 pandemic restriction period, it was critical to explore how these factors affected PA behaviors of youth and what socio-ecological factors promoted PA during this crisis. Through this nationally distributed survey, the findings of this study provide an understanding of how environmental disparities (i.e., crime, traffic, recreational access) and COVID-19 restrictions may result in changes of youth obesity-related PA and play behaviors during public crises.

A series of systemic reviews [18, 20, 34] supported that changes in the built environment are associated with changes of PA behaviors in both children and adolescents. Wong and colleagues [35], for example, reported that neighborhoods with features that encouraged playing/walking with more sport facilities are related to increased weekly frequency of leisure-time MVPA (> 3 times/week) among adolescents. Our results also confirmed that the supportive neighborhood

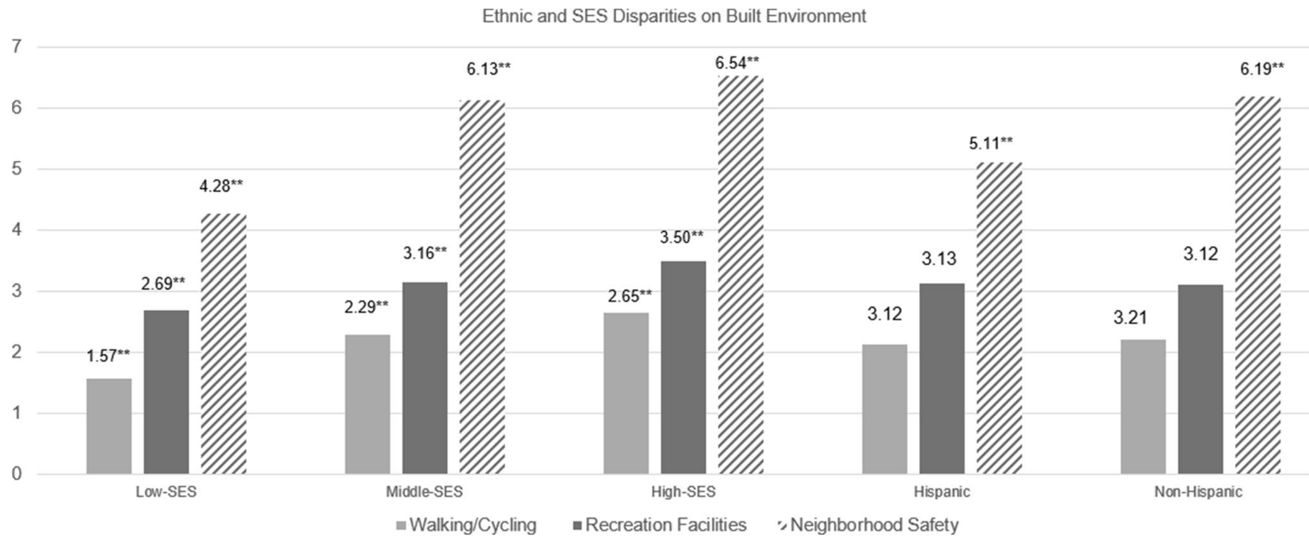

Fig. 4 Ethnic and SES disparities in built environment. *Note.* SES = Socioeconomic status; * $p < .05$. ** $p < .01$

walking/cycling infrastructure and more recreation facilities increased US youth's leisure-time MVPA as well as various outdoor play behaviors during COVID-19. Using SEM technique, one unique finding of this study was that parents' perceptions of neighborhood safety/traffic were directly associated with play behaviors during COVID-19 regardless of the influences of COVID-19 restrictions. On the other hand, youth's ability to respond to COVID-19 restrictions may add more detrimental effects on changes of LPA and MVPA (full mediation model) beyond the negative effect caused by the fear of crime and unsafe neighborhoods on PA participation, during COVID-19 pandemic.

The results also suggest that built environments have different impacts on surrounding diverse residences. Consistent with the literature [23, 34], low-SES and minority groups are more likely to have limited community facilities/resources and perceive fewer safe areas to play in their neighborhoods and yard compared to their high-SES and non-minority peers. These findings provided insights for future purposeful programming as well as budgeting of public parks and indoor/outdoor recreation facilities to reduce ethnic and SES disparities in PA, especially during public crises. Most analyses found that intervention effect of built environment on PA did not significantly differ in ethnic minority or SES groups [34]. Consistent with previous literature [36], the significant effects of SES on PA, independent of race/ethnicity has been observed in this national survey data. However, we found that lower-SES and Hispanic minority groups perceived less safe walking and playing areas in their neighborhoods compared to their middle-/high-SES non-Hispanic peers during COVID-19 restrictions.

Although the statistical differences regarding the ethnic disparities in PA and play behavior were not found in this study, it is noteworthy, to observe the direct and indirect influences of neighborhood safety on changes of LPA, MVPA, and play behaviors, during COVID-19 pandemic restrictions, that were confirmed in the SEM models. Inequality in neighborhood resources and availability of PA facilities and environments may contribute to ethnic and SES disparities in PA, which maybe a long-term detrimental factor of increased risk of physical inactivity and overweight patterns. The findings of this study lead us to suggest infrastructure improvements (e.g., enhancing neighborhood walkability, quality of parks and playgrounds, and providing adequate active transport infrastructure) are likely to result in positive impacts on PA in children and adolescents. As Cohen and colleagues noted [22], public parks are critical for PA in minority communities and their numbers are insufficient, and ethnic disparities may result in more health issues during global pandemics. In addition, the possibility that infrastructure improvements focusing on adding monitoring systems on walking/cycling trails and reducing the traffic in neighborhoods, may benefit socioeconomically disadvantaged groups during a pandemic and health crisis, which warrants further exploration and evaluations.

Conclusion

The findings of this study provide meaningful insights on promoting PA more equitably during a pandemic and suggest group-specified planning for more PA as cities relax social distancing ordinances and shelter-in-place restrictions. Overall, neighborhoods characterized with a high safety index (less traffic and low crime rate) provided more opportunities for PA that resulted in less amounts of MVPA reduction during COVID-19 pandemic restriction period. Active children perceived significantly higher values on the built environment (supportive recreation resources, more recreational PA opportunities) compared to the inactive children during the pandemic, however the difference did not reach the significant level between two groups before the pandemic. More research is needed to assess safety elements of parks and playgrounds that are associated with MVPA of youth during social restrictions. Parks and playgrounds opened sooner than schools and sports program in most communities during the COVID-19 pandemic restrictions and some did not close. As an element in built environments, public parks and playgrounds may be a critical solution to maintaining and increasing youth's PA [22].

The results suggest those neighborhoods with single or apartment housing (90.6% of our sample) or located in/adjacent to the center of the city (92.8% of our sample live in urban/city) may be affected more by the COVID-19 pandemic restrictions especially on children's MVPA changes. Moreover, neighborhoods with low values of land use, more public recreational facilities, and additional safe and walkable areas may indirectly eliminate the magnitudes of PA reduction caused by the social distancing and shelter-in-place mandates. Considering the negative influences of the social distancing and shelter-in-place restrictions on changes of PA and play behaviors, built environments such as walkability and less traffic/crime provided feasible indices that may be used to maintain and increase MVPA levels during a global pandemic. We acknowledged that most of the participants in this study were White, which limits the generalizability of the findings to the population as a whole. Future studies may focus on a racially or ethnically diverse sample, which will provide opportunities to undertake subgroup analyses to determine the element of ethnic inequalities in health behaviors. Using self-reported measures on PA and built environment may present a response bias, using both self-report and objective measures (e.g., accelerometers, GIS) in the future research are recommended. Taken together, these findings provide new evidence for continued investigation of tailored built environment interventions and policies that can help groups (e.g., low SES) reduce health disparities, advance health equity, and stay active and resilient during and after the COVID-19 pandemic and future crises.

Author's Contribution All authors contributed to the study conception, design, and data collection. XG contributed to conceptualization, methodology, software, formal analysis, investigation, writing—original draft, writing—review and editing, and visualization. JK and TZ contributed to conceptualization, methodology, investigation, and writing—review and editing. DD, HR, and KJ contributed to methodology, resources, and writing—review and editing. WS, JB, and JV contributed to data curation, investigation, and writing—review and editing. KT contributed to conceptualization, methodology, data curation, writing—review and editing, and supervision. All authors read and approved the final manuscript.

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Data Availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code Availability Not applicable.

Declarations

Ethics Approval This study was approved by the UT Southwestern Medical School Institutional Review Board (IRB). Participants signed the consent before the data collection.

Conflicts of Interest The authors report no conflicts of interest for this study.

References

1. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. JAMA - J Am Med Assoc. 2018;320(19):2020–8. https://doi.org/10.1001/jama.2018.14854.
2. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999–2016. Pediatrics. 2018;141(3):1999–2016. https://doi.org/10.1542/peds.2017-3459.
3. Weihrauch-Blüher S, Kromeyer-Hauschild K, Graf C, et al. Systematic Review Current Guidelines for Obesity Prevention in Childhood and Adolescence Weihrauch-Blüher et al.: Current Guidelines for Obesity Prevention in Childhood and Adolescence. Obes Facts. 2018;11:263–76. https://doi.org/10.1159/000486512.
4. Jordan RE, Adab P, Cheng KK. Covid-19: Risk factors for severe disease and death. BMJ. 2020;368. https://doi.org/10.1136/bmj.m1198
5. Rundle AG, Park Y, Herbstman JB, Kinsey EW, Wang YC. COVID-19–Related School Closings and Risk of Weight Gain Among Children. Obesity. 2020;28(6):1008–9. https://doi.org/10.1002/oby.22813.
6. Tulchin-Francis K, Stevens W, Gu X, et al. The impact of the coronavirus disease 2019 pandemic on physical activity in U.S. children. J Sport Heal Sci. 2021;10(3):323–32. https://doi.org/10.1016/J.JSHS.2021.02.005.
7. Sallis JF, Adlakha D, Oyeyemi A, Salvo D. An international physical activity and public health research agenda to inform coronavirus disease-19 policies and practices. J Sport Heal Sci. 2020;9(4):328. https://doi.org/10.1016/j.jshs.2020.05.005.
8. Van Lancker W, Parolin Z. COVID-19, school closures, and child poverty: a social crisis in the making. Lancet Public Heal. 2020;5(5):e243–4. https://doi.org/10.1016/S2468-2667(20)30084-0.
9. Hemphill NM, Kuan MTY, Harris KC. Reduced Physical Activity During COVID-19 Pandemic in Children With Congenital Heart Disease. Can J Cardiol. 2020;36(7):1130–4. https://doi.org/10.1016/j.cjca.2020.04.038.
10. Sheikholeslami S, Ghanbarian A, Azizi F. The impact of physical activity on non-communicable diseases: Findings from 20 years of the Tehran lipid and glucose study. Int J Endocrinol Metab. 2018;16(4 Suppl):84740. https://doi.org/10.5812/ijem.84740.

11. Caye A, Rocha TB-M, Anselmi L, et al. Attention-Deficit/Hyperactivity Disorder Trajectories From Childhood to Young Adulthood. JAMA Psychiatry. 2016;73(7):705. https://doi.org/10.1001/jamapsychiatry.2016.0383.
12. Center for Health Statistics N. *Healthy People 2030*. https://www.cdc.gov/nchs. Accessed August 25, 2020.
13. Parker L, Burns AC, Sanchez E. Committee on Childhood Obesity Prevention Actions for Local Governments Food and Nutrition Board Board on Children, Youth, and Families Board on Population Health and Public Health Practice Transportation Research Board; 2009. http://www.nap.edu. Accessed August 25, 2020.
14. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating active living communities. Annu Rev Public Health. 2006;27(1):297–322. https://doi.org/10.1146/annurev.publhealth.27.021405.102100.
15. Durand CP, Andalib M, Dunton GF, Wolch J, Pentz MA. A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. Obes Rev. 2011;12(5):e173–82. https://doi.org/10.1111/j.1467-789X.2010.00826.x.
16. Loprinzi PD, Cardinal BJ, Loprinzi KL, Lee H. Benefits and Environmental Determinants of Physical Activity in Children and Adolescents. Obes Facts. 2012;5(4):597–610. https://doi.org/10.1159/000342684.
17. Sallis JF, Kerr J, Carlson JA, et al. Evaluating a Brief Self-Report Measure of Neighborhood Environments for Physical Activity Research and Surveillance: Physical Activity Neighborhood Environment Scale (PANES). Vol 7.; 2010. https://doi.org/10.1123/jpah.7.4.533
18. Tuulie Koivumaa-Honkanen H, Korpelainen R, Kärmeniemi M, Lankila T, Ikäheimo T, Koivumaa-Honkanen H. The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. Ann Behav Med. 2018;52(3):239–51. https://doi.org/10.1093/abm/kax043.
19 Rhodes RE, Saelens BE, Sauvage-Mar C. Understanding physical activity through interactions between the built environment and social cognition: A systematic review. Sport Med. 2018;48(8):1893–912. https://doi.org/10.1007/S40279-018-0934-0.
20 McGrath LJ, Hopkins WG, Hinckson EA. Associations of objectively measured built-environment attributes with youth moderate–vigorous physical activity: A systematic review and meta-analysis. Sport Med. 2015;45(6):841–65. https://doi.org/10.1007/S40279-015-0301-3.
21. Sallis JF, Botchwey N, Floyd MF, et al. Building evidence to reduce inequities in youth physical activity and obesity: Introduction to the physical activity research center (parc) special section. Prev Med (Baltim). 2019;129:105767. https://doi.org/10.1016/J.YPMED.2019.105767.
22. Cohen DA, Han B, Williamson S, et al. Playground features and physical activity in U.S. neighborhood parks. Prev Med (Baltim) 2020;131:105945. https://doi.org/10.1016/J.YPMED.2019.105945
23. Gordon-Larsen P, Nelson MC, Page P, Popkin BM. Inequality in the Built Environment Underlies Key Health Disparities in Physical Activity and Obesity. Pediatrics 2006;117(2). https://doi.org/10.1542/peds.2005-0058
24. Cereijo L, Gullón P, Cebrecos A, et al. Access to and availability of exercise facilities in Madrid: An equity perspective. Int J Health Geogr. 2019;18(1):15. https://doi.org/10.1186/s12942-019-0179-7.
25. Marquet O, Aaron Hipp J, Alberico C, et al. Park use preferences and physical activity among ethnic minority children in low-income neighborhoods in New York City. Urban For Urban Green. 2019;38:346–53. https://doi.org/10.1016/j.ufug.2019.01.018.
26. Pietrobelli A, Pecoraro L, Ferruzzi A, et al. Effects of COVID-19 lockdown on lifestyle behaviors in children with obesity living in Verona, Italy: A longitudinal study. Obesity. 2020:0–3. https://doi.org/10.1002/oby.22861
27. Sallis JF, Adlakha D, Oyeyemi A, Salvo D. An international physical activity and public health research agenda to inform coronavirus disease-19 policies and practices. J Sport Heal Sci. 2020. https://doi.org/10.1016/j.jshs.2020.05.005.
28 Watson KB. Disparities in Adolescents' Residence in Neighborhoods Supportive of Physical Activity — United States, 2011–2012. MMWR Morb Mortal Wkly Rep. 2019;65(23):598–601. https://doi.org/10.15585/MMWR.MM6523A2.
29 Conderino SE, Feldman JM, Spoer B, Gourevitch MN, Thorpe LE. Social and economic differences in neighborhood walkability across 500 U.S. cities. Am J Prev Med. 2021;61(3):394–401. https://doi.org/10.1016/J.AMEPRE.2021.03.014.
30. Godin G. *Number 1 COMMENTARY Health & Fitness Journal of Canada*. Vol 4.; 2011. https://doi.org/10.14288/HFJC.V4I1.82
31. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform. 2019;95:103208. https://doi.org/10.1016/J.JBI.2019.103208.
32. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377–81. https://doi.org/10.1016/J.JBI.2008.08.010.
33. MacKinnon DP, Fairchild AJ, Fritz MS. Mediation analysis. Annu Rev Psychol. 2007;58:593–614. https://doi.org/10.1146/annurev.psych.58.110405.085542.
34. Smith M, Hosking J, Woodward A, et al. Systematic literature review of built environment effects on physical activity and active transport – an update and new findings on health equity. Int J Behav Nutr Phys Act. 2017;14(1):1–27. https://doi.org/10.1186/S12966-017-0613-9.
35. Yee B, Wong M, Lo W-S, Cerin E. Longitudinal relations of perceived availability of neighborhood sport facilities with physical activity in adolescents: An analysis of potential moderators. Artic J Phys Act Heal. 2013. https://doi.org/10.1123/jpah.2012-0077.
36. Giles-Corti B, Donovan RJ. The relative influence of individual, social and physical environment determinants of physical activity. Soc Sci Med. 2002;54(12):1793–812. https://doi.org/10.1016/S0277-9536(01)00150-2.
37. Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and obesity in disadvantaged populations. 2009:31(1):7-20. https://doi.org/10.1093/epirev/mxp005

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