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Greenspace, physical activity, and BMI in children from two cities in northern Mexico

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ABSTRACT

Numerous previous studies have reported positive associations between exposure to greenspace and children's physical activity, but in high-income countries only. Prior studies have also examined greenspace and obesity in children, but these have yielded inconsistent results and focused mostly on older children. The purpose of this study was to assess associations between time children spent in greenspace as the primary exposure and our outcomes of interest, including 1) minutes of physical activity, and 2) body mass index (BMI) z-score. Our sample was 102 children ages 3 to 5 years living in Ensenada and Tijuana, Mexico. We fit linear mixed models to estimate associations between greenspace and children's physical activity and BMI z-score. After adjustment for potential confounders, greater time in greenspace was associated with decreased sedentary time (−0.08 min per hour for each additional 30 min in greenspace; 95% CI −0.13, −0.04; $p = 0.002$) and increased moderate-to-vigorous physical activity (MVPA) (0.06; 95% CI 0.03, 0.10; $p < 0.001$). Results were driven primarily by children in Tijuana (−0.22; 95% CI −0.38, −0.06; $p = 0.008$ for sedentary time and 0.15; 95% CI 0.06, 0.38; $p = 0.007$ for MVPA). Time in greenspace was not associated with BMI z-score in children in Ensenada (0.001; 95% CI −0.008, 0.01; $p = 0.83$) or Tijuana (−0.009; 95% CI −0.02, 0.004; $p = 0.17$). Greater time in greenspace was associated with physical activity but not BMI in our sample of children—more so in Tijuana compared to Ensenada. Given high rates of obesity, interventions should aim to increase physical activity in young children in Northern Mexico.

1. Introduction

Physical activity in early childhood has been positively associated with gross motor milestone achievement, enhanced fitness, improved psychosocial health, and decreased adiposity (Carson et al., 2017; Schmutz et al., 2018). Increasing physical activity in young children is a public health priority, as many children do not achieve recommended levels (Carson et al., 2017; Galaviz et al., 2016; Schmutz et al., 2018). Active travel, especially to school, is one way to increase children's physical activity (Larouche et al., 2018; Martin et al., 2016; Schoeppe et al., 2013). Additionally, children's environments – especially outdoor environments – may play an important role in promoting their overall health (Davison and Lawson, 2006; Mitchell and Popham, 2008). Researchers have consistently found that children were more active outside (Hinkley et al., 2016; Schmutz et al., 2017; Tonge et al., 2016) and increased their physical activity in seasons when the weather is mild and conducive to outdoor active play (Atkin et al., 2016; Hjorth et al., 2013; Rich et al., 2012; Ridgers et al., 2015, 2018; Schmutz et al., 2018). During outdoor play, children may spend time in greenspaces, like parks and playgrounds. Greenspace is often defined as any open land area that is publicly accessible and at least partially covered with grass, trees, or other vegetation (United States Environmental Protection Agency, 2018).

Numerous previous studies have reported positive associations between exposure to greenspace and children's physical activity—especially moderate-to-vigorous physical activity (MVPA) (McCrorie et al.,

Abbreviations: BMI, body mass index; GPS, global positioning system; MVPA, moderate-to-vigorous physical activity; NDVI, Normalized Difference Vegetation Index

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2014; Ward et al., 2016). Prior studies have also examined greenspace and obesity in children, but have found inconsistent results (Sanders et al., 2015a, 2015b; Schalkwijk et al., 2018; Schule et al., 2016; Wilhelmsen et al., 2017). Some found that exposure to greenspace was associated with lower risk of obesity or lower weight status in children (Schalkwijk et al., 2018). These studies, however, all took place in high-income countries, including Germany (Schule et al., 2016), New Zealand (Gray et al., 2015; Sanders et al., 2015a, 2015b; Ward et al., 2016), Norway (Wilhelmsen et al., 2017), the United Kingdom (UK) (Lachowycz et al., 2012; Schalkwijk et al., 2018; Wheeler et al., 2010), and the United States (US) (Almanza et al., 2012; Cerin et al., 2016).

Little is known about associations between greenspace and physical activity in children living in less-developed countries like Mexico, where rates of childhood obesity are comparable to the US (Corvalan et al., 2017; Rivera et al., 2014). As a result, recent public health efforts and interventions in Mexico have targeted modifiable risk factors, including physical activity, to help prevent obesity in children (Aceves-Martins et al., 2016; Galaviz et al., 2012, 2016; Perez-Escamilla, 2016; Polo-Oteyza et al., 2017). In Mexico, national recommendations refer to the US-based guidelines of the National Association for Sport and Physical Education (NASPE) that suggest children should spend at least 120 min per day in active play (Perez-Escamilla, 2016). Some evidence suggests that young children in Mexico are not engaging in sufficient physical activity and exceed recommendations for sedentary time (Galaviz et al., 2016; Miranda-Rios and Vasquez-Garibay, 2017). According to one prior study, this may be due to a combination of unsafe outdoor play conditions and a lack of appropriate places for outdoor physical activity (Avelar Rodriguez et al., 2018). We aimed to fill a number of gaps in the research literature, including focusing on a middle-income country to assess association between greenspace, physical activity, and obesity in young children. Therefore, the purpose of this study was to assess time children spent in greenspace using an objective global positioning system (GPS) device and associations with physical activity using accelerometers in two cities in Northern Mexico. Secondarily, we were interested in measuring the relation between greenspace and children's body mass index (BMI). We measured our exposures and outcomes at two times over a one-year study period. We hypothesized that greenspace would be associated with both physical activity and obesity in children and that children's levels of physical activity would increase over the one-year study period as they got older.

2. Material and methods

2.1. Study design and sample

For this longitudinal study, we recruited a sample of children living in Ensenada and Tijuana, Mexico. We assessed the same children during the 2012–2013 school year (baseline) and again during the 2013–2014 school year (follow up). To be eligible, children had to be 3 to 4 years of age at baseline, be living in Ensenada or Tijuana, and not have any disabilities that would impact their ability to be physically active in greenspace. We excluded children whose parents were planning to move out of Ensenada or Tijuana within the next 12 months. To recruit families, we first mailed letters to the principals of all public and private primary schools in Ensenada (n = 23) and Tijuana (n = 5) (despite Tijuana being a much larger city, it is home to fewer schools). With permission from the principal (80% from each city agreed), we then contacted parents of children entering primary school for the first time in the 2012–2013 school year by mail and followed up by phone. Additionally, we received calls from parents who were referred from other parents whose children were already enrolled in the study, so some recruitment took place through word-of-mouth. We ultimately enrolled a number of children (26.5% of our total sample) not associated with our initial target schools. We communicated with a total of 297 parents to assess their interest in participating in the study. Of those, 153 were interested, 49 refused, and two were not eligible. Of the 153 who expressed interest, 102 completed baseline and 87 completed follow-up assessments. This work was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). Parents provided written informed consent for themselves and their children for this experimentation with human subjects. This study was approved by the Duke University Institutional Review Board.

2.2. Measures

2.2.1. Location and greenspace

Our exposure was time children spent in greenspace. To assess their physical location, children wore a portable Qstartz BT-Q1000X (Qstarz International, Taipei, Taiwan) GPS device on a belt that we placed on the left hip for one continuous week. We instructed parents to remove the device when children were sleeping, bathing, or swimming, and to charge the device at night. Parents logged sleep and wake times, and removal and replacement of the device. We instructed parents to keep the GPS devices on children at all times, even when in the family home. Therefore, we considered time spent in the home as non-greenspace and these data points contributed to our overall binary exposure described below. We programed GPS devices to record location information at 60-second intervals to balance frequency of data collection and battery life.

We used the Normalized Difference Vegetation Index (NDVI) to conceptualize greenspace, which is a validated measure of neighborhood greenness (Rhew et al., 2011). The NDVI captures green vegetation density. Values for the NDVI range from −1 to 1, with higher values indicating greater density of green vegetation. To aid interpretation, previous studies have categorized NDVI as 0.1 or less = barren rock (or sand), 0.2–0.5 = sparse vegetation, and 0.6–0.09 = dense vegetation (Beyer et al., 2014). Negative NDVI values typically indicate blue space (*i.e.*, water). Based on prior studies (Beyer et al., 2014; Zubair and Weilert, 2014), we defined greenspace as NDVI values ≥ 0.2 and non-greenspace as < 0.2. We derived NDVI values at a spatial resolution of 30 m using LANDSAT 8 Thematic Mapper satellite images from April 2013, as we began study recruitment, and applied values to our geographic regions of interest using ArcGIS 10.2 software (ArcGIS 10, ESRI Inc., Redlands, California, USA).

2.2.2. Physical activity

To measure physical activity duration and intensity, children wore a GT3X+ monitor (ActiGraph, Pensacola, Florida, USA) on a belt on the right hip (opposite the GPS device) for one continuous week. We instructed parents to leave the monitor on when children were sleeping, but to remove it during bathing or swimming. We configured monitors to sample activity at 30 Hz but aggregated data into 5-second epochs. We classified activity into sedentary, light, moderate, or vigorous activity (and moderate to vigorous physical activity; MVPA) using Pate cut-points, which have been validated for use with children in our age group (Pate et al., 2006) and were used in a prior study of greenspace and physical activity in preschoolers (Cerin et al., 2016). Specifically, these cut-points per 5-second epoch were as follows: 0–65 = sedentary; 66–139 = light; 140–277 = moderate; and ≥280 = vigorous. In a sensitivity analysis, we also applied the cut-points proposed by Evenson et al. (2008) of 0–12 = sedentary, 13–190 = light, 191–333 = moderate; ≥334 = vigorous. Prior to analysis, we used parent logs to remove data associated with time children spent sleeping. We calculated the total number of minutes per day of each level of physical activity and then standardized physical activity to minutes per hour by dividing the total minutes of wear time throughout the day (hours the device was actually worn per child) by 60.

2.2.3. Body mass index

Trained research assistants measured child weight and standing height without shoes and in light clothing at each assessment in triplicate using standard techniques (Shorr, 1986). We then calculated

BMI z-scores using World Health Organization age- and sex-specific reference data (Acta Paediatr., 2006).

2.2.4. Other measures

We collected demographic information from mothers during each in-person assessment. We documented child age, child gender, maternal age, and the number of years the mother had lived in the area (either Ensenada or Tijuana) through maternal questionnaires. We also assessed the number of children and adults living in the household and annual household income (≤5000 pesos, 5001–10,000 pesos, or ≥10,000 pesos).

2.2.5. Data merging and processing

We first overlaid NDVI data onto the GPS data using ArcGIS. We then merged accelerometer data from 5-second epochs and GPS data from 60-second epochs. Using linear interpolation, we calculated the expected 5-second NDVI value to correspond with the 5-second physical activity data. We classified accelerometer data with > 60 min of consecutive zeros as non-wear time (Troiano et al., 2008). We included children with at least 4 valid days of combined accelerometer and GPS data, with a valid day defined of at least 8 h of daytime monitor (both GPS and accelerometer) wear time per day. Because our main exposure was time spent in green space, we excluded any GPS data that were likely to reflect motorized activity, defined as a GPS unit recording speeds > 25 km per hour. While GPS devices record speed, we also manually calculated distance by time between GPS observations to remove times when children appeared to be engaging in motorized travel. We also visually displayed GPS points to check for and remove outliers. We further extracted data points from rasters using bilinear interpolation. The values extracted for each point are influenced by their distance from the center of a pixel, as well as the values of and distance from adjacent pixels.

2.3. Analysis

We calculated means (standard deviation; SD) for continuous demographic variables and percentages for categorical variables. For the primary aim, we fit linear mixed models with a child-level random intercept to estimate the association between time children spent in greenspace and minutes of physical activity (sedentary, light, moderate, vigorous, and MVPA), standardized to minutes per hour. Secondarily, we were interested in assessing associations between greenspace and BMI z-score. We used data from baseline and follow up and present results from analyses examining Ensenada only, Tijuana only, and both cities combined. We used a temporal decay structure to account for the correlation between the repeated measurements within each child. To account for within-subject association, we used a temporal correlation with a power decay function. This allowed us to account for the fact that children could complete the follow-up assessments at different timepoints, relative to baseline. We adjusted for covariates that were of *a priori* interest, including child age, child gender, household income, assessment period, and accelerometer wear time for the physical activity analysis only. We present results in terms of parameter estimates for each additional 30 min spent in greenspace, along with 95% CI, and two-sided *p* values. We conducted all analyses using SAS 9.4 (SAS Institute, Cary, North Carolina, USA) at a significance level of < 0.05.

3. Results

3.1. Descriptive statistics

Of the 102 children (n = 52 in Tijuana and n = 50 in Ensenada) who enrolled at baseline, 87 children (n = 47 in Tijuana and n = 40 in Ensenada) completed assessments at follow up (85% retention rate). The mean (SD) time between assessments was 9.7 (3.0) months. Child age at study enrollment was 4.5 (0.5) years in Tijuana and 3.9 (0.6) years in Ensenada (Table 1). In Tijuana, 52.9% of children were female, compared to 42.9% in Ensenada. The mean (SD) NDVI was 0.17 (0.6) in Tijuana and 0.20 (0.4) in Ensenada; NDVI values are displayed geographically in Fig. 1.

Table 1
Characteristics of the children and families in the Juega study, by city (n = 102).

	Ensenada (n = 50)	Tijuana (n = 52)
Child	*Mean (SD)*	
Age, years	3.9 (0.6)	4.5 (0.5)
Body mass index z-score	1.0 (1.6)	1.0 (1.2)
	Percent (number)	
Gender, female	42.9 (21)	52.9 (27)
Body mass index category		
Underweight	2.0 (1)	0.0 (0)
Normal weight	77.6 (38)	78.4 (40)
Overweight	8.2 (4)	9.8 (5)
Obese	12.2 (6)	11.8 (6)
Family	*Mean (SD)*	
Maternal age, years	29.4 (6.8)	33.3 (6.6)
Number of years mother lived in area	21.9 (10.8)	22.6 (12.0)
Number of adults in household	2.7 (1.3)	2.6 (1.1)
Number of children in household	1.9 (1.2)	1.9 (1.1)
	Percent (number)	
Household income, monthly		
≤5000 pesos (~$275 USD)	37.5 (18)	40.4 (21)
5001–10,000 pesos (~$276–$549 USD)	37.5 (18)	32.7 (17)
≥10,001 pesos (~$550 USD)	25.0 (12)	26.9 (14)

3.2. Physical activity results

Results from analyses using the Pate cut-points were relatively indistinguishable from sensitivity analyses, where we used the Evenson cut-points. Therefore, we used the Pate cut-points in all analyses. Children were sedentary for a mean (SD) of 47.5 (2.6) and 47.6 (2.3) and minutes per hour at baseline in Tijuana and Ensenada, respectively (Table 2). Children spent an average of 7.0 (1.8) and 7.0 (1.6) minutes per hour in MVPA in Tijuana and Ensenada, respectively. There was little change in sedentary time or physical activity between baseline and follow up. After adjustment for potential confounders, greater time in greenspace (NDVI values ≥0.2) was associated with decreased sedentary time (−0.08 min of sedentary time per each additional 30 min in greenspace; 95% CI −0.13, −0.04; $p = 0.002$) and increased MVPA (0.06; 95% CI 0.03, 0.10; $p < 0.001$) for both cities combined (Table 3). Results were driven primarily by children in Tijuana (−0.22; 95% CI −0.38, −0.06; $p = 0.008$ for sedentary and 0.15; 95% CI 0.06, 0.38; $p = 0.007$ for MVPA). Results were similar for all other levels of physical activity.

3.3. BMI results

Children had a mean (SD) BMI z-score of 1.0 (1.2) in Tijuana and 1.0 (1.6) in Ensenada. After adjustment for potential confounders, greater time in greenspace was not associated with BMI z-score for children in Tijuana (−0.009; 95% CI −0.02, 0.004; $p = 0.17$) or Ensenada (0.001; 95% CI −0.008, 0.01; $p = 0.83$) (Table 4).

4. Discussion

We found that greater time in greenspace was associated with both decreased sedentary time and increased MVPA. These findings were largely driven by children in Tijuana, where greenspace was positively associated with all types of physical activity, and negatively associated with sedentary time. Conversely, in Ensenada, time spent in greenspace was associated with MVPA and vigorous physical activity only. These findings are generally consistent with previous studies of children in

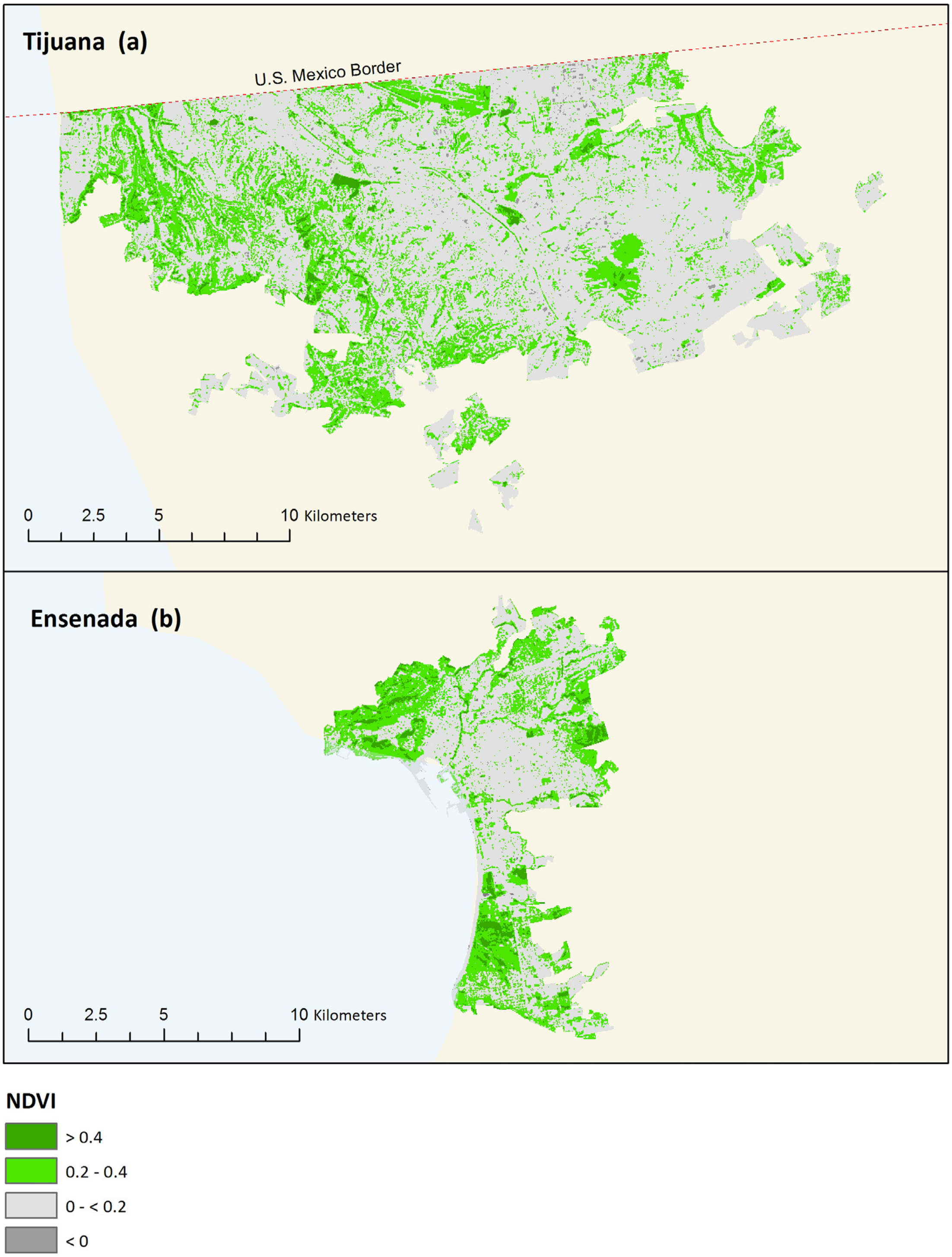

Fig. 1. Normalized Difference Vegetation Index (NDVI) values to conceptualize greenspace (green vegetation density) in Tijuana (a) and Ensenada (b).

high-income countries (Almanza et al., 2012; Cerin et al., 2016; Lachowycz et al., 2012; Ward et al., 2016; Wheeler et al., 2010). For example, Ward et al. (2016) observed a similar association between greenspace and MVPA in children in New Zealand. Almanza et al. (2012) found that children were 34% more likely to engage in MVPA in greenspace in the US. Similarly, Wheeler et al. (2010) observed a 37% greater likelihood of MVPA in greenspace in the UK. In another study of UK children, Lachowycz et al. (2012) found that one-third (week day) to nearly one-half (weekend day) of time children spent engaging in MVPA was in greenspace. However, these previous studies included children of slightly older ages compared to our sample and all took place in high-income countries. One prior study of 3- to 5-year-olds found that children had 43% higher odds of engaging in MVPA while outdoors, but this study also took place in a high-income country (the US). Despite these differences in child age and location, we also found that greater time spent in greenspace was associated with increased MVPA. This similarity is important, given that this is the first study of greenspace and physical activity in children living in a middle-income country.

However, contrary to prior studies, we did not observe any change in physical activity over the one-year study period as we had expected. Children in our study spent about 7 min per hour engaged in MVPA at

Table 2
Unadjusted minutes per hour of physical activity and inactivity, by city.

Physical activity	Baseline Mean (SD) (n = 102)		Follow up Mean (SD) (n = 87)	
	Ensenada	Tijuana	Ensenada	Tijuana
Sedentary	47.6 (2.3)	47.5 (2.6)	48.0 (2.6)	47.2 (2.8)
Light	5.4 (0.9)	5.5 (1.0)	5.1 (0.8)	5.4 (1.1)
Moderate	4.5 (0.9)	4.6 (1.1)	4.3 (1.1)	4.6 (1.1)
Vigorous	2.5 (0.8)	2.4 (0.8)	2.5 (1.0)	2.8 (1.0)
Moderate to vigorous	7.0 (1.6)	7.0 (1.8)	6.8 (1.9)	7.4 (1.9)

Table 3
Adjusted[a] estimates and 95% confidence intervals (CI) from analyses examining greenspace and minutes per hour of physical activity and inactivity, overall and by city (n = 87).

Physical activity	Both cities combined		Tijuana		Ensenada	
	Estimate (95% CI)	*p*-Value	Estimate (95% CI)	*p*-Value	Estimate (95% CI)	*p*-Value
Sedentary	−0.08 (−0.13, −0.03)	0.002	−0.22 (−0.38, −0.06)	0.008	−0.04 (−0.10, 0.01)	0.14
Light	0.02 (−0.002, 0.04)	0.08	0.07 (0.005, 0.13)	0.04	0.003 (−0.02, 0.03)	0.82
Moderate	0.03 (0.01, 0.05)	0.004	0.08 (0.01, 0.14)	0.02	0.02 (−0.005, 0.04)	0.14
Vigorous	0.03 (0.02, 0.05)	< 0.001	0.07 (0.02, 0.13)	0.007	0.02 (0.005, 0.04)	0.009
Moderate to vigorous	0.06 (0.03, 0.10)	< 0.001	0.15 (0.06, 0.38)	0.007	0.04 (0.004, 0.07)	0.03

[a] Adjusted for child age, child gender, family income, assessment, and accelerometer wear time.

Table 4
Adjusted[a] estimates and 95% confidence intervals (CI) from analyses examining greenspace and body mass index (BMI) z-score, overall and by city (n = 87).

	Both cities combined		Tijuana		Ensenada	
	Estimate (95% CI)	*p*-Value	Estimate (95% CI)	*p*-Value	Estimate (95% CI)	*p*-Value
BMI z-score	−0.002 (−0.01, 0.005)	0.50	−0.009 (−0.02, 0.004)	0.17	0.001 (−0.008, 0.01)	0.83

[a] Adjusted for child age, child gender, family income, and assessment.

both baseline and follow-up. Conversely, previous studies have observed increases in physical activity over time in young children. For example, in a longitudinal study of 555 preschoolers in Switzerland, researchers observed increases in physical activity levels over a one-year period (Schmutz et al., 2018). Despite this, the researchers noted few modifiable individual factors associated with this change in children's physical activity. Having siblings in the home was the only factor associated with a change in physical activity (Schmutz et al., 2018). Additionally, in a recent systematic review, researchers noted maternal modeling as the one variable associated with an increase in physical activity in preschoolers over time (Hesketh et al., 2017). However, we did not formally test for differences in physical activity between baseline and follow-up assessments due to our relatively small sample size.

Additionally, children in our study were sedentary for nearly three-quarters of every hour—slightly more than preschoolers in other countries (Jones et al., 2017), including China (Ji et al., 2018), Finland (Maatta et al., 2018), Switzerland (Schmutz et al., 2018), the UK (Jago et al., 2017), and the US (Borkhoff et al., 2015; Colley et al., 2013; Espana-Romero et al., 2013; Ruiz et al., 2018). There is evidence that sedentary behaviors, including television and screen media use, track from early to later life (Matton et al., 2006; McVeigh et al., 2016; Smith et al., 2015). Thus, it is especially important to identify and target interventions to reduce sedentary time in young children in Northern Mexico.

We also did not detect an association between greenspace and BMI z-score. Prior studies examining greenspace and obesity in children have found inconsistent results (Sanders et al., 2015a, 2015b; Schalkwijk et al., 2018; Schule et al., 2016; Wilhelmsen et al., 2017). There is some indication of an association between greenspace and lower BMI in older children and among boys but not girls in previous studies (Sanders et al., 2015a, 2015b). Similarly among adults, studies on the relation of greenspace and BMI also present mixed findings (Cummins and Fagg, 2012; Lachowycz and Jones, 2011; Lee et al., 2017; Pearson et al., 2014; Richardson et al., 2017; Sander et al., 2017). Some prior studies observed an association among women and younger adults only (Richardson et al., 2017; Sander et al., 2017). We may not have observed an association in our study for a number of reasons. Our sample size may have been insufficient to detect differences and the majority of the children in our study were not overweight or obese. Ward et al. (2016) also attributed their lack of significant associations to these same sample characteristics. Next, our sample of children was of younger ages and the association may emerge as children age. Wheeler et al. (2010), Ekelund et al. (2004), and Sanders et al. (2015a) all observed small but significant associations between greenspace and BMI in a sample of slightly older school-age children. Third, we were not able to stratify analyses by gender, given the small number of children in the study.

Additionally, NDVI considers dense vegetation as greenspace, which may not be conducive to active play. However, a recent study evaluated associations between various measures of greenspace and observed the strongest associations between NDVI greenness and both physical activity and obesity (Klompmaker et al., 2018). One study cautioned against using a homogenous greenspace exposure and instead argued for an assessment of the types and qualities of natural environments (Wheeler et al., 2015). Despite this, numerous previous studies have assessed children's exposure to parks, playgrounds, and gardens as a measure of greenspace (Cerin et al., 2016; Cohen et al., 2006; Lachowycz et al., 2012; Roemmich et al., 2006; Schalkwijk et al., 2018; Simen-Kapeu et al., 2010). We also did not examine physical activity that took place in other settings throughout Ensenada and Tijuana. In a recent systematic review, McGrath et al. found that a greater proportion of children's physical activity took place in streets and urban venues, compared to greenspace (McGrath et al., 2015). Thus, it is important to assess geographic locations where greenspaces and outdoor active play may be more limited.

Moreover, we were not able to assess children's exposure to blue space like lakes, rivers, and oceans. Blue space has been defined previously by Foley and Kistemann (2015) as health-enabling places and spaces, where water is at the center, for the promotion of wellbeing. Researchers are beginning to examine proximity to water and its relation to physical activity and childhood obesity (White et al., 2014; Wood et al., 2016). For example, Wood et al. found that coastal proximity was associated with lower rates of obesity in adults for rural areas and small towns, but not for larger urban cities (Wood et al., 2016). In our study, children living in Ensenada, a coastal city, may have engaged in physical activity in and around Bahía de Todos Santos—an inlet of the Pacific Ocean. However, we were not able to capture time children spent in blue space. We used an activity monitor to measure physical activity and a GPS device that were not water resistant, and thus, instructed children to remove them prior to swimming or bathing. In future studies, researchers could use water-resistant or waterproof devices to assess the association between blue space and physical activity or obesity in children living in coastal cities, such as Ensenada.

As noted above, this study has limitations. The relatively small sample size, drawn from two cities in Northern Mexico, limits generalizability. We also experienced some attrition in this study, which further limits our ability to extrapolate results to other populations of children in Mexico. We also did not examine children's exposure to parks and playgrounds and focused instead on NDVI. When we conducted the study, Ensenada and Tijuana had few dedicated parks and playgrounds, so this was not a feasible exposure at the time. We also included time children spent in the family home when calculating our exposure variable. Previous studies have excluded GPS points at the home location (Almanza et al., 2012). However, we were interested in examining time children spent in the home so we opted to include them, consistent with some prior studies (Cerin et al., 2016; Lachowycz et al., 2012). We also programmed our GPS device to collect data every 60 s to preserve the battery, rather than a more frequent interval assessment. Finally, we did not include a random effect for school in the analysis, although we intended to do so based on our initial recruitment strategy. We ultimately enrolled children outside of our target schools, making the clusters relatively small. However, this study also has strengths. We used objective measures of both greenspace (GPS devices) and physical activity (accelerometers) in this study. Our weight outcome in children was also measured by trained research assistants. Moreover, the longitudinal design further strengthens our ability to draw conclusions about our findings. As the first study to take place in a Mexico – a middle-income country – we provide further evidence of an association between greenspace and physical activity in young children.

5. Conclusions

Recent calls to action highlight the importance of promoting physical activity and decreasing sedentary time for young children, especially for those younger than five years (American Academy of Pediatrics APHA and National Resource Center for Health and Safety in Child Care and Early Education, 2011; Larson et al., 2011; Institute of Medicine, 2011). Despite this, few previous studies have focused on greenspace and young children. This study found that children in Northern Mexico were more active—for MVPA in particular—while in greenspace. This is the first study, to our knowledge, to evaluate associations between greenspace and physical activity in Mexico—all prior studies have been conducted in high-income countries. The two cities (Ensenada and Tijuana) targeted in our study have a history of crime and violence and may not be fully conducive to outdoor active play. Despite this, we found clear associations between time children spent in greenspace and physical activity. A recent qualitative study found that low-income families in deprived urban areas experienced a number of barriers to accessing greenspace (Cronin-de-Chavez et al., 2019). Families in the study recognized the importance of spending time in greenspace, especially with their young children, but expressed concern about where to access greenspace and how to manage children in these spaces. However, this study took place in a high-income country. We were also not able to assess time children spent in blue spaces like water on the coast of Ensenada. Identifying places where young children are most active is especially important to help inform intervention and policy efforts to increase physical activity (Colabianchi et al., 2016). Future studies focusing on low- and middle-income countries (like Mexico) should consider evaluating greenspace, blue space, and other locations such as parks and playgrounds where outdoor active play may be common for young children.

Conflicts of interest statement

The authors do not have any competing financial or conflicts of interests to report.

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