# The Effect of Proximity to Parks on Childhood Obesity*

Yiwei Qian[a], Arya B. Gaduh[b], Michael R. Thomsen[c], Rodolfo M. Nayga Jr[d],

Grant H. West[e] and Heather L. Rouse[f]

*June 2015*

**Abstract**

Inadequate physical activities are associated with increased obesity among children in the United States. Using a 2004-2007 panel dataset of children in Northwest Arkansas, we examine whether proximity to neighborhood parks – where children can be physically active – is associated with a lower body mass index (BMI). Using covariate matching, we estimate the average treatment effect (on the untreated) of neighborhood parks proximity on children's BMI. We find that the exposure of neighborhood parks around the home environment has significant and negative effects on rural children's BMI z-scores. In particular, the effects are significant and negative for rural females, especially 5-9 year old females. Finally, we employ a difference-in-differences (DID) model combined with matching methods to measure the effect of new parks exposure. We find evidence that for rural children, new neighborhood parks have a beneficial effect on children's BMI z-scores with longer time exposure.

*JEL Classification codes:* I10

**Keywords**: childhood obesity, build environment, parks, covariate matching, difference-in-differences estimation.

---

* This research was funded by the Agriculture and Food Research Initiative of the USDA National Institute of Food and Agriculture, grant number 2011-68001-30014. This work was also partly supported by the National Research Foundation of Korea (NRF-2011-330-B00074).

[a] Corresponding author. Department of Agricultural Economics and Agribusiness, University of Arkansas, 217 Agriculture Building, Fayetteville, AR 72701, USA. E-mail address: yqian@uark.edu

[b] Sam M.Walton College of Business, Department of Economics, University of Arkansas

[c] Department of Agricultural Economics and Agribusiness, University of Arkansas

[d] Department of Agricultural Economics and Agribusiness, University of Arkansas; Adjunct Professor, Korea University and Norwegian Institute for Bioeconomy Research.

[e] Department of Agricultural Economics and Agribusiness, University of Arkansas

[f] Arkansas Center for Health Improvement, University of Arkansas for Medical Sciences

Obesity prevalence among children and adolescents in the United States has increased significantly during the past few decades (Ogden et.al. 2014). Inadequate physical activities among children may be responsible for the increasing rates of obesity (Anderson et al. 1998). Previous research shows that a high proportion of children and adolescents do not obtain the recommended amount of physical activity (Troiano et al. 2008). Almost 23 percent of students in grades 9–12 in the United States did not participate in at least 60 minutes of physical activity on at least one day over a week (NYRBS 2009). Kelley, Kelley and Pate (2014) found that exercise significantly reduced children's BMI z-scores and Trost et al. (2001) found that obese children engaged in significantly less physical activity on a daily basis than non-obese children.

We study how proximity to parks is associated with BMI z-scores. Parks and playgrounds are important spaces where children can be physically active (Blanck et al. 2012). Previous studies have found negative correlations between the proximity of parks and obesity outcome (Potwarka, Kaczynski and Flack 2008; Singh, Siahpush and Kogan 2010a; Wolch et al. 2011; Veugelers et al. 2008; Fan and Jin 2014). We use high quality data with precise location information to measure the average treatment effects of neighborhood parks on the BMI z-score of the untreated group. Furthermore, we investigate whether exposure to new neighborhood parks impacted BMI z-scores through a difference-in-differences (DID) model.

We employ a covariate matching (CVM) estimator similar to that employed by Fan and Jin (2014). However, this article differs from theirs in important ways. Fan and

Jin (2014) used a cross-sectional dataset from the 2007 National Survey of Children's Health that reflect a random sample of households across the United States. Furthermore, the exposure of parks in their dataset is self-reported. In contrast, although our geographic focus on Northwest Arkansas is much narrower, it allows us to acquire geocoded park locations and to identify the opening dates of new parks. The proximity measure is also based on the exact geographic coordinates of the residences of children in our sample. The outcome variable is drawn from a BMI screening program of public school children and provides repeated observations from the same child over time. Access to this panel dataset allows us to measure the effects of different durations of exposure to parks.

Arkansas has a relatively high childhood obesity rate and so represents an important context within which to examine factors that contribute to this problem. The National Survey of Children's Health indicated that in Arkansas, about 32.8 percent of 10-17 year old children were either obese or overweight in 2003 and this percentage increased to 37.5 percent in 2007 (NCSL 2015). Moreover, we focus on a region of the state that has experienced considerable economic growth over the past three decades, has received a positive net inflow of population from other regions of the US, and encompasses a range of community sizes, which allows us to examine whether the effects of parks are different for urban and rural children in our sample.

We find that neighborhood parks have a significant and negative effect on rural children's BMI z-scores; i.e. that a three-mile proximity to parks in a rural area is associated with a 0.167 reduction in BMI z-scores. Our results also show that girls living in rural areas are more likely to benefit from neighborhood parks. Specifically, estimations for subgroups show that girls in the younger age cohort (5-9 years old) have a significant park effect. Additional DID models provide evidence that, for rural children, new neighborhood parks have a beneficial effect on children's BMI z-scores with longer time exposure.

The next section describes the data sources and the variables used in the analysis. Section 3 discusses the empirical strategy we used to identify the effect of neighborhood parks on children's BMI z-score. Section 4 presents the results. Section 5 discusses the additional DID analysis. Finally, section 6 concludes and provides suggestions for future research and policy interventions.

## Data

Our data come from several sources. First, we use the Arkansas BMI data from 2004 to 2007. Beginning with the 2003-2004 school year, Arkansas became the first state to screen public schoolchildren for unhealthy body weight. Due to concerns about the high rates of childhood obesity, the Arkansas Assembly passed Act 1220 of 2003 that mandated the collection of annual BMI data by the Arkansas Center for Health Improvement (ACHI) (Justus et al. 2007). Children's weight and height data are collected annually by trained personnel in the public schools according to uniform statewide protocols. BMI is calculated as a ratio ([weight in pounds / (height in inches)$^2$]

× 703) and then converted to age-gender specific z-scores using the Centers for Disease Control and Prevention guidelines (CDC 2015).[1] In addition to the BMI z-scores, the Arkansas BMI dataset includes demographic information such as the child's age, gender, ethnicity, and whether the child was eligible for free school lunches or reduced price lunches. We also include controls for the neighborhood food environment (i.e. fast food restaurants) using geo-coded business lists obtained from Dun and Bradstreet (D&B). Our dataset includes BMI screenings of children that ranged in ages from 5 to 16 years old during the initial 2003/2004 school year.[2]

Second, we assembled data on park locations from a variety of sources. We acquired the Arkansas Public Lands GIS data layer in 2007 from the Arkansas Highway and Transportation Department (AHTD), disseminated through the Arkansas GIS data clearing house known as Geostor.[3] We crossed-checked this information with municipalities in Northwest Arkansas. Parks that were not already represented in the AHTD data layer were added using ESRI ArcGIS for Desktop© to complete the parks layer. We contacted parks officials from Benton, Washington, Crawford, and Sebastian counties in northwestern Arkansas to learn the opening or closing date for each park. During this process, we verified the existence of 152 parks in each area during 2004-2007. Figure 1 provides a map of the parks in our study area.

After acquiring the parks data, we overlaid the coordinates of parks onto the residential coordinates of students in the BMI data for each year and computed the networked distance from the student's residence to the nearest park.[4] Dummy variables are used to measure park access. These represent the presence of parks within varying distances of a child's residence, for children in urban and rural areas, respectively. We also computed the education level, income level, and marital status for the neighborhood of the child's residence using census block group data from the 2009 American Community Survey, which provides five-year averages by block group for the 2005 to 2009 period. These control variables are listed in table 1.

Table 1 presents descriptive statistics for the variables used in our study. There are 17,219 observations in our panel data. 12,414 (6,681 are male and 5,733 are female) students always lived in an urban area and 4,805 (2,578 are male and 2,227 are female) students always lived in rural area during the 2004-2007 period of our study. For those living in urban areas, nearly 11.8 percent (11.4 percent for male, 12.2 percent for female) have at least one park within a half mile of their residence. For those living in rural places, about 12.8 percent (13.0 percent for male, 12.6 percent for female) of students have at least one park within three miles of their residence.

**Empirical Strategy**

The proximity of parks to individuals is a non-random event. There are two possible threats to identifying the causal effects of parks on children obesity. First, new parks may be placed endogenously and factors that affect park placement may be related to body weight. Second, households may also endogenously sort themselves near existing parks due to unobservable factors that are correlated with children's BMI. Hence, we employ two methodologies: a CVM model and a DID model to address these selection issues.[5]

Following Fan and Jin (2014), we apply CVM to identify and quantify the impact of neighborhood parks on childhood BMI. The goal of CVM is to find a group of untreated individuals that are similar to the treated individuals in all pre-treated observable characteristics and then measure the average treatment effect for these groups with similar characteristics.

We separate the analysis between children in urban and rural areas and by gender.[6] We match urban and rural children separately because park density differs greatly in urban and rural areas. Consequently, in urban areas we define those who have consistently been exposed to parks within half-a-mile – a walkable distance even for young children – of their residences during the 2004-2007 period as the treatment group. Among the sample of urban children, 11.8 percent have at least one park within a half mile of their residence. To maintain comparability, for the rural areas, we chose a distance in which a similar proportion of children reside. We therefore chose three miles since 12.8 percent of rural children have at least one park within that radius. We define as untreated children those who were never exposed to parks during the 2004-2007 time period. To ensure a consistent exposure over the study period, we restrict our sample to children that were in the same residence in 2004 as they were in 2007. We also excluded children living within a half (three) mile of one of the new parks that opened during the 2004-2007 period in the urban (rural) areas.[7] The children in the treatment group were then matched to children in the untreated group based on the 2004 (the initial year) observable characteristics of the children.

We also match male and female subsamples separately because males and females experience substantially different metabolic processes and types of body development when they are teenagers and adolescents (Tarnopolsky 1999) and neighborhood amenities may affect males and females differently (Gomez et al. 2004; Fan and Jin 2014). Additionally, we employ the matching on different age subgroups (5-9 years old and 10-16 years old).

An advantage of CVM is that it allows exact matching on certain variables (Abadie and Imbens, 2011). We matched the children exactly based on age, ethnicity, lunch status, and 2004 weight status. It is important to use age as one of the matching variables because our sample spans ages during which there is rapid growth and increasing autonomy in food choices and time use (Haywood 1991). Ethnicity also needs to be controlled precisely because there are significant differences in BMI and obesity prevalence across racial groups (Caprio et al. 2008; Taveras et al. 2010). We use the free and reduced lunch status variables as a proxy of family income.[8] Income status is an important variable that has been shown to affect childhood obesity (Wang 2001; Casey et al. 2001; Singh, Siahpush and Kogan 2010b). The second is the individual's 2004 weight status, whether the child was underweight, normal weight, overweight or obese. Finally, we matched, but not exactly, on neighborhood variables (measured at the census block group level) reflecting educational attainment and family structure within the neighborhood. These factors have also been found to influence childhood obesity (Nayga 2000; Singh, Siahpush and Kogan 2010b; Anderson, Butcher and Levine 2003).

Understanding the potential park effect on childhood obesity in neighborhoods without a park is the relevant policy question. We therefore focus on estimating the average treatment effects of neighborhood parks on the untreated group (ATU). The ATU estimate can be written as follows:

$$ATU = E[Y_{1i} - Y_{0i} | K_i = 0]$$

where $Y_{1i}$ denotes the potential outcome variable for individual i in the treatment group and $Y_{0i}$ denotes the potential outcome variable for individual i in the untreated group. In this analysis, we use the child's BMI z-score in 2007 as the outcome variable. $K_i$ denotes the neighborhood park status for individual i.

**Results and Discussion**

We first show how CVM improves identification in our context. Table 2 presents the results of the balance tests, which measure how similar the matching variables are between the treated and untreated groups before and after matching. A pre-match comparison of the treatment and untreated groups shows significant differences on age, ethnicity, income level and neighborhood environment. After matching, the differences between the samples exist only for some of the neighborhood variables for which we did not require exact matches. These differences, however, are very small.

The first row of table 3 shows the average treatment three-year effect of neighborhood parks on the BMI z-score of the untreated groups. For urban children, proximity to a park within half a mile of the residence has no significant effect on BMI z-score. For rural children, parks within three miles of a child's residence have a significant and negative effect on BMI z-score. The estimate suggests that for rural children who have park access within three miles of their residence from 2004-2007, their BMI z-scores in 2007 are 0.167 lower than children who do not have access to a park. To put this into context, for a 10 year old boy residing in a rural area who has a height of 150 cm, this result suggests a decrease in his weight from 40.1 kg to 39.2 kg; and for a 10 year old girl residing in a rural area with 150 cm height, it would be a decrease from 41 kg to 40 kg.[9]

Table 3 also presents the heterogeneous three-year effects for males and females, separately, in urban and rural areas. For urban boys and girls, there are no significant effects of neighborhood parks on BMI z-scores. There is also no significant effect for rural boys. Interestingly, the effect of parks in rural areas is driven primarily by the subsample of girls (0.295 reduction in BMI z-score and significant at the 0.01 level). For a 10 year-old rural female of 150 cm height, this amounted to a decrease from 40.6 kg to 38.8 kg.[10] This result is consistent with Fan and Jin (2014) who find that girls are more likely to be affected by neighborhood parks than boys. Singh, Siahpush and Kogan (2010a) also suggested that girls are more vulnerable than boys to less favorable neighborhood built environmental conditions with respect to obesity outcomes. Since girls are less likely to be engaged in outdoor physical activity (Troiano et al., 2008; Trost et al., 2002; Pate et al., 2004), lack of favorable outdoor space like parks may have greater effect on body weight.

To reduce the bias that might arise from the differences in the unobservable characteristics of children living in deeply-rural areas, we dropped 1,534 children who live more than 15 miles from the park from the sample and re-estimated the model. The results, which are reported in table 3, suggest that our original results are robust to the deletion of these deeply rural children on rural girls. Specifically, the park effects on rural females continues to be negative and statistically significant with similar coefficient magnitudes (-0.40) as those presented earlier in the table. For a 10 year old rural female with 150 cm height, this amounts to a decrease in weight from 40.6 kg to 38.2 kg.

As further robustness checks, table 3 also presents the ATU estimates for one year and two years.[11] The ATU for rural children is negative and but statistically insignificant for one year effect (-0.061), and for two years (-0.051). The estimates for rural females are also negative and insignificant for these years (-0.088 for one year and -0.078 for two years). For urban males, urban females and rural males, the estimates are also insignificant. These results suggest that for rural children, especially for rural girls, longer exposure to parks leads to lower weight gain. For urban children, the park effects for these shorter periods continue to be insignificant both economically and statistically.

Estimates for the different age subgroups are reported in table 4, the results show that the treatment effects arise primarily from the sample of younger rural girls aged 5-9 (-0.278, significant at 0.05 level). Among the older cohort of rural girls, aged 10-16, the estimate continues to be negative (-0.141) but is not statistically significant. For boys living in rural areas, the proximity to parks decrease the BMI z-score for both 5-9 age cohorts (-0.121) and 10-16 age cohorts (-0.119) but neither estimate is statistically different from zero. For children living in urban areas, the proximity to parks also decreases the BMI z-score for boys and girls in the 5-9 age cohort but increases the BMI outcome for girls in 10-16 age cohort. All the effects for urban children are insignificant.

**The Effect of New Parks**

As discussed above, assignment to the treatment group or untreated group is not a random event. While the use of CVM controls for the observable characteristics, households could have sorted themselves by locating near existing parks prior to 2004 (the initial year of our sample) based on characteristics not accounted for in the set of matching variables. For this reason, we also employ a DID model to measure the effect of new parks as an additional analysis.  It is important to point out that the children affected by these new parks were excluded by the sample selection criteria we used for the CVM analysis above.  In this respect, the DID analysis provides a robustness check on the effects of parks using a different sample as well as a different methodology.

For the DID analysis, we only include children who did not move between 2004 and 2007 and compare those who lived near a newly-opened park to those who do not.  In our study region, five new parks were built in 2005, three were built in 2006, and six were built in 2007.[12] However, the number of observations for rural children affected by parks constructed in 2006 and 2007 was less than 10 and the conditions under which we are allowed to analyze the Arkansas BMI data preclude analysis of small samples. Hence, we identify the children that were exposed to new parks opening in 2005. An advantage is that this also ensures prolonged exposure after the park opened. The untreated group for the DID model includes those who were not exposed to a park from 2004 to 2007. The treated group includes those who were not exposed to a park in 2004, but were then exposed to one (or more) new park(s) that opened in 2005. As in the analysis above, we use a half mile treatment threshold for urban children and a three mile threshold for rural children. Because there is a limited number of observations from children with new park openings, we only estimate the model for subsamples of rural and urban children but cannot examine the effects separately by gender or age. [13] The DID model for individual *i* and time *t* is specified as:

$$Y_{it} = \alpha_i + \beta_1 T_{it} + \beta_2 Treat_i + \beta_3 DID_{it} + \delta X'_{it} + \epsilon_{it}$$

where $Y_{it}$ denotes the BMI z-score; $T_{it}$ is the period dummy which equals to one if time *t* falls in period with exposure to a new park; $Treat_i$ is the treatment dummy which equals one if the individual is in treatment group; $DID_{it}$ is the DID interaction term; $X'_{it}$ is a control variable vector;[14] and $\epsilon_{it}$ is the error term. Before estimating the DID model, we match the treated individuals to the three nearest neighbors in the control group using the same variables used in the original CVM analysis presented above.

We then run the DID model for different lengths of exposure separately with matches from the same control group. So we conducted separate DID analysis for: (1)

those with 3 years of exposure where the years of exposure are 2005, 2006 and 2007, (2) those with 2 years of exposure where the years of exposure are 2005 and 2006, (3) those with only 1 year of exposure where the year of exposure is just 2005. Hence, the year before park exposure in these analyses is always 2004.

Results from the DID models are presented in table 5. In general, the effects maybe imprecisely estimated given the small sample size. However, the results suggest that the beneficial effects of parks were mainly experienced by rural children. Parks built during 2005 have a positive effect on BMI z-score for one year of exposure (0.059) but negative effects for two (-0.014) and three years exposure (-0.052). While the DID estimates of the park effect are not statistically different from zero, the sign of the effect for longer periods of exposure is consistent with our findings for rural children and rural girls that longer exposure to a new neighborhood park can reduce the BMI.

**Conclusions**

Fighting the childhood obesity epidemic requires increasing opportunities for physical activity, which can be facilitated by the presence of neighborhood parks. We find that the proximity of neighborhood parks to the residence of children can have significant and negative effects on the BMI z-scores of children who live in rural areas. Our results suggest that rural girls (especially for younger girls) are significantly affected by neighborhood parks. The park effect is not significant for urban children and rural boys. This heterogeneous effect by gender is consistent with findings from previous studies

(Fan and Jin 2014; Singh, Siahpush and Kogan 2010a). The robustness analysis shows that for rural children and rural girls, the park effects are larger and more significant for longer-term exposure than short-term exposure. Our DID estimation provided us a robustness check and consistent results that, for rural children, the park effects are more likely to be negative and get larger in absolute value for longer-term exposure, even though the coefficient is not statistically significant due to limited number of observations and statistical power.

Differences in the barriers for children's physical activities may offer an explanation for the heterogenous effects between urban and rural areas. In less urbanized areas, transportation costs and potentially hazardous environment are larger barriers for rural children to do outdoor physical activities (Moore et.al. 2010). This might explain why increasing proximity to parks is more effective in rural areas. Moreover, since girls may be less likely to engage in vigorous physical activities than boys (Troiano et al. 2008; Trost et al. 2002; Pate et al. 2004) and less likely to use recreational space (i.e., school playground, playing fields, courts and recreational center) (Chomitz et.al. 2011), proximity to parks is also likely to affect girls more since it may be conducive to outdoor play. Trost et al. (1996) found that confidence in overcoming barriers to physical activity and participation in community physical activity programs are factors related to the gender differences in physical activity. Since neighborhood parks are major places for community physical activity programs in rural areas, girls who live close to a park may have more chance to participate in these programs and do physical activity. Moreover, younger girls have been found to be more likely to be affected by bad built environment (i.e. unsafe community, poor sidewalk, etc.) (Singh, Siahpush and Kogan, 2010a), which may explain why younger girls in rural areas can be affected more by neighborhood parks.

Some of the limitations of the current study provide opportunities for future research. For example, future research could further test the robustness of our findings in other locations. It would also be interesting to examine the effect of other types of built environment (e.g., trails, gyms, or parks with varying amenities, etc.) on children's physical activities since this could also provide policy-relevant knowledge that can be used to address the problem of childhood obesity in the United States

---

[1] BMI z-score is defined as a deviation of the value for an individual from the mean value of the reference population divided by the standard deviation for the reference population.

[2] The BMI dataset includes children from kindergarten to the 12th grade. However, since we focus on the individuals who were or were not exposed to a park over our four-year study period, the ages of children in the initial year fell within this range.

[3] Parks from this dataset were selected based on their designated types. Included types are 'City Park', 'Park', 'City Municipal Park', and 'City Park- Ball Fields', while excluded types are 'City Park- US Army Corps of Engineers and Campsite', 'Recreational Area- Campsite and Picnic', 'Park and Campsite', 'Wayside Park- Information', 'Recreation Area', 'Park/Public Use Area'.

[4] Network distance is defined as the shortest distance from one point to another following a network of roads instead of a straight line.

[5] The DID model is presented in Section 5.

[6] Urban and rural statuses are defined by the American Community Survey.

[7] There were 14 new parks that opened during the 2004-2007 period in northwest Arkansas.

[8] Free and reduced lunch status is used to define income level of households. To receive a free meal, household income must lie below 130% of the Federal poverty threshold, and to receive a reduced-price meal, household income must lie below 185% of the Federal poverty threshold, as defined by the U.S. Office of Management and Budget.

[9] The initial weight is calculated based on a BMI z-score of 0.521, the average for rural children in 2004.

[10] The initial weight is calculated based on a BMI z-score of 0.457, the average for rural girls in 2004.

[11] The only difference in these analyses is we use BMI z-score in year 2006 and year 2005 as outcome variables for the two-year and one-year effects, respectively. The number of observations in the treated group and untreated group is as in the original model.

[12] There was no park closing during this period.

[13] Due to the confidentiality agreement with ACHI, we are not allowed to estimate results with less than 20 individual observations.

[14] The control variables include age, gender dummy, race dummy, free lunch status dummy, reduced lunch status dummy, dummy for living in an urban area, dummy for access to grocery store, and counts of fast food restaurants in one mile from residence.

**References**

Abadie, A., and G.W. Imbens. 2011. "Bias corrected matching estimators for average treatment effects". *Journal of Business and Economic Statistics* 29(1):1–11.

Anderson, P.M., K.F. Butcher, and P.B. Levine. 2003. "Maternal employment and overweight children". *Journal of Health Economics* 22(3): 477-504.

Andersen, R.E., C.J. Crespo, S.J. Bartlett, L.J. Cheskin, and M. Pratt. 1998."Relationship of physical activity and television watching with body weight and level of fatness among children." *Journal of the American Medical Association,* 279(12): 938-942.

Blanck, H.M., D. Allen, Z. Bashir, N. Gordon, A. Goodman, D. Merriam & C. Rutt. 2012. "Let's go to the park today: the role of parks in obesity prevention and improving the public's health." *Childhood Obesity*, *8*(5): 423-428.

Caprio, S., S.R. Daniels, A.Drewnowski, F.R. Kaufman, L.A. Palinkas, A. L. Rosenbloom, and J. B. Schwimmer. 2008. "Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment a consensus statement of shaping America's health and the obesity society." *Diabetes care*, 31(11): 2211-2221.

Casey, P.H., K. Szeto, S. Lensing, M. Bogle, and J. Weber. 2001. "Children in food-insufficient, low-income families: prevalence, health, and nutrition status. " *Archives of Pediatrics & Adolescent Medicine* 155(4): 508-514.

Center for Disease Control and Prevention. 2015. "*About BMI for children and teens.*" Available at:

http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html

Chomitz, V.R., D.B. Aske, J.McDonald, H.Cabral, and K.A.Hacker. 2011."The role of recreational spaces in meeting physical activity recommendations among middle school students." *Journal of Physical Activity and Health*, 8(1): 8-16.

Fan, M., and Y. Jin. 2014."Do neighborhood parks and playgrounds reduce childhood obesity?" *American Journal of Agricultural Economics*, 96(1): 26-42.

Gomez, J. E., B. A. Johnson, , M. Selva, &J. F. Sallis. 2004. "Violent crime and outdoor physical activity among inner-city youth" *Preventive medicine*, *39*(5): 876-881.

Guo, S. S., and W. C. Chumlea. 1999. "Tracking of body mass index in children in relation to overweight in adulthood. "*The American Journal of Clinical Nutrition*, 70(1): 145-148.

Haywood, K.M. 1991. "The Role of Physical Education in the Development of Active Lifestyles." *Research Quarterly for Exercise and Sport* 62:151–156.

Justus, M.B., K.W. Ryan, J. Rockenbach, C. Katterapalli, and P. Card-Higginson. 2007. "Lessons learned while implementing a legislated school policy: body mass index assessments among Arkansas's public school students." *Journal of School Health* 77(10): 706-713.

Kelley, G.A., K. S. Kelley, & R. R. Pate. 2014. "Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis." *BMC pediatrics*, 14(1): 225.

Moore, J.B., S.B. Jilcott, K.A. Shores, K.R. Evenson, R.C. Brownson, and L. F. Novick. 2010."A qualitative examination of perceived barriers and facilitators of physical activity for urban and rural youth." *Health Education Research* 25(2): 355-367.

National Conference of State Legislatures. 2015. Childhood Overweight and Obesity Trend. Available at: http://www.ncsl.org/research/health/childhood-obesity-trends-state-rates.aspx

National Youth Risk Behavior Survey Overview (NYRBS). 2009. Available at http://www.cashe.org/wp-content/uploads/2011/01/yrbs.sum_.2009.pdf

Nayga, R. M. 2000. "Schooling, health knowledge and obesity." *Applied Economics* 32(7): 815-822.

Ogden, C.L., M.D. Carroll, B.K. Kit, and K.M. Flegal.2014. "Prevalence of childhood and adult obesity in the United States, 2011-2012." *The Journal of the American Medical Association*, 311(8): 806-814.

Pate, R.R., K.A. Pfeiffer, S.G. Trost, P.Ziegler, and M.Dowda. 2004."Physical activity among children attending preschools." *Pediatrics*, 114 (5): 1258-1263.

Potwarka, L. R., A.T. Kaczynski, and A.L. Flack. 2008."Places to play: association of park space and facilities with healthy weight status among children." *Journal of community health*, 33(5): 344-350.

Singh, G.K., M. Siahpush, and M.D. Kogan. 2010a. "Neighborhood socioeconomic conditions, built environments, and childhood obesity." *Health Affairs*, 29(3): 503-512.

Singh, G.K., M. Siahpush, and M.D. Kogan. 2010b. “Rising social inequalities in US childhood obesity, 2003–2007.” *Annals of Epidemiology* 20(1): 40-52.

Taveras, E.M., M.W. Gillman, K.Kleinman, J.W. Rich-Edwards, and S. L. Rifas-Shiman. 2010."Racial/ethnic differences in early-life risk factors for childhood obesity." *Pediatrics* 125(4): 686-695.

Troiano, R. P., D. Berrigan, K. W. Dodd, L. C. Masse, T. Tilert, and M. McDowell. 2008. “Physical activity in the United States measured by accelerometer”. *Medicine and science in sports and exercise*, 40(1):181-188.

Trost, S.G., L. M. Kerr, Dianne S. Ward, and R. R. Pate. 2001."Physical activity and determinants of physical activity in obese and non-obese children."*International journal of obesity,* 25 (6): 822-829.

Trost, S.G., R.R. Pate, J.F. Sallis, P.S. Freedson, W.C. Taylor, M.Dowda, and J.Sirard. 2002. "Age and gender differences in objectively measured physical activity in youth." *Medicine and science in sports and exercise,* 34(2): 350-355.

Trost, S.G., R.R. Pate, M.Dowda, R.Saunders, D.S. Ward, and G.Felton. 1996."Gender differences in physical activity and determinants of physical activity in rural fifth grade children." *Journal of School Health,* 66(3): 145-150.

Veugelers, P., F. Sithole, S. Zhang, and N. Muhajarine. 2008.” Neighborhood characteristics in relation to diet, physical activity and overweight of Canadian children.” *International Journal of Pediatric Obesity*. 3(3):152–159.

Wang, Y. 2001. “Cross-national comparison of childhood obesity: the epidemic and the relationship between obesity and socioeconomic status.” *International Journal of Epidemiology* 30(5): 1129-1136.

Wolch, J., M. Jerrett, K. Reynolds, R. McConnell, R. Chang, N.Dahmann &K. Berhane. 2011. “Childhood obesity and proximity to urban parks and recreational resources: A longitudinal cohort study.” *Health & place*, *17*(1): 207-214

**Figure 1. Parks map of northwestern Arkansas in 2007**

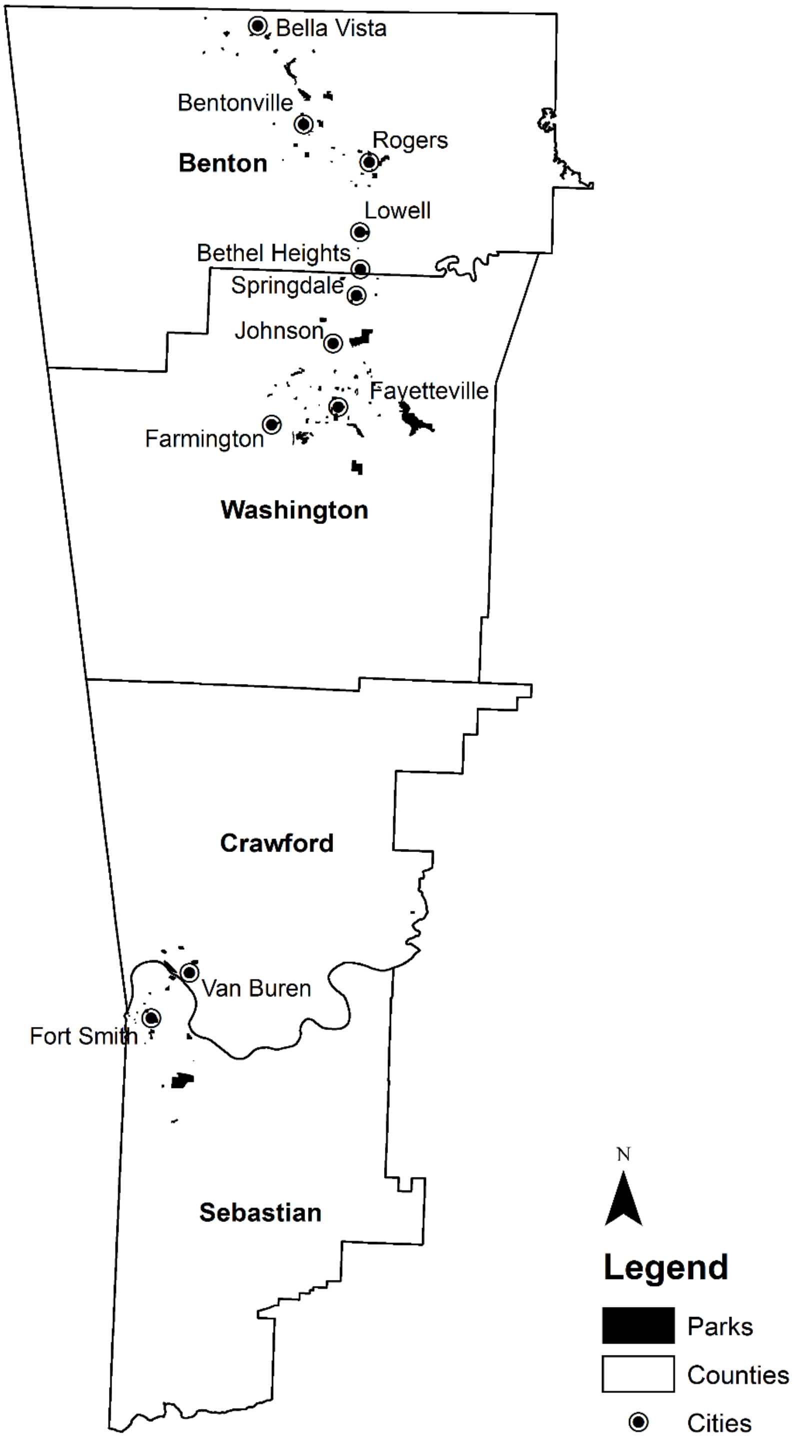

**Table 1. Description and Descriptive Statistics of Variables in the Study (N=17,219)**

| Variables | Description | Mean | | | |
|---|---|---|---|---|---|
| | | Urban | | Rural | |
| | | Male | Female | Male | Female |
| **Outcome Variables** | | | | | |
| BMI z-score | Individuals' BMI z-score in 2007 | 0.644<br>(1.026) | 0.486<br>(0.962) | 0.578<br>(1.03) | 0.456<br>(0.955) |
| **Treatment Variables** | | | | | |
| Park_Half | If the distance between individual's residence and nearest park is less or equal to 0.5 miles, then =1, 0 otherwise | 0.114<br>(0.363) | 0.122<br>(0.366) | 0.002<br>(0.045) | 0.004<br>(0.063) |
| Park_Three | If the distance between individual's residence and nearest park is less or equal to 3 miles, then =1, 0 otherwise | 0.816<br>(0.387) | 0.823<br>(0.381) | 0.130<br>(0.332) | 0.126<br>(0.331) |
| **Control Variables** | | | | | |
| Age* | Age of student | 9.60<br>(2.80) | 9.36<br>(2.75) | 9.92<br>(2.83) | 9.70<br>(2.81) |
| White* | Binary indicator (if individual is White then =1, 0 otherwise) | 0.696<br>(0.459) | 0.681<br>(0.465) | 0.914<br>(0.279) | 0.917<br>(0.274) |
| Black* | Binary indicator (if individual is African American then =1, 0 otherwise) | 0.033<br>(0.180) | 0.039<br>(0.194) | 0.005<br>(0.067) | 0.004<br>(0.060) |
| Hispanic* | Binary indicator (if individual is Hispanic then =1, 0 otherwise) | 0.219<br>(0.414) | 0.229<br>(0.420) | 0.051<br>(0.220) | 0.049<br>(0.217) |
| Free or Reduced* | Binary indicator (if individual always participated in free and reduced lunch from 2004-2007 then =1, 0 otherwise) | 0.302<br>(0.459) | 0.322<br>(0.467) | 0.185<br>(0.388) | 0.195<br>(0.396) |
| Under Weight* | Binary indicator (if individual weight status is underweight in 2004 then =1, 0 otherwise) | 0.014<br>(0.120) | 0.016<br>(0.123) | 0.020<br>(0.138) | 0.013<br>(0.115) |
| Normal Weight* | Binary indicator (if individual weight status is normal in 2004 then =1, 0 otherwise) | 0.628<br>(0.483) | 0.692<br>(0.461) | 0.652<br>(0.476) | 0.715<br>(0.451) |
| Overweight* | Binary indicator (if individual weight status is overweight in 2004 then =1, 0 otherwise) | 0.170<br>(0.376) | 0.165<br>(0.371) | 0.154<br>(0.361) | 0.147<br>(0.354) |
| Single Mother Prop | Proportion of families that have children under 18 with female householder with no husband present | 0.203<br>(0.167) | 0.207<br>(0.173) | 0.144<br>(0.119) | 0.149<br>(0.122) |
| High School Prop | Proportion of population with high school degree | 0.292<br>(0.093) | 0.291<br>(0.091) | 0.352<br>(0.078) | 0.350<br>(0.078) |
| Some College Prop | Proportion of population with some college or an associate's degree | 0.271<br>(0.085) | 0.268<br>(0.087) | 0.278<br>(0.071) | 0.282<br>(0.078) |
| College Plus Prop | Proportion of population with college and post-graduate degrees | 0.231<br>(0.156) | 0.227<br>(0.155) | 0.200<br>(0.114) | 0.198<br>(0.116) |
| Below Pov Prop. | Proportion of population below the poverty level | 0.155<br>(0.119) | 0.161<br>(0.126) | 0.105<br>(0.080) | 0.107<br>(0.083) |
| No Vehicle Prop | Proportion of families with no vehicle availability | 0.053<br>(0.057) | 0.054<br>(0.058) | 0.029<br>(0.029) | 0.029<br>(0.030) |
| Observations | | 6,681 | 5,733 | 2,578 | 2,227 |

Note: Standard errors appear in parenthesis.
*: Variables included in exact matching list.

**Table 2. Balance Test of Matching Covariates**

| **Variables** | | **Differences** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Urban** | | | **Rural** | | |
| | | *All* | *Male* | *Female* | *All* | *Male* | *Female* |
| Age | Unmatched | -0.066 | -0.176 | 0.02 | -0.055 | -0.118 | 0.031 |
| | Matched | 0.016 | 0.010 | 0.011 | -0.034 | -0.001 | 0.039 |
| White | Unmatched | -0.017 | -0.042 | 0.011 | 0.059*** | 0.056*** | 0.063*** |
| | Matched | -0.005 | -0.004 | -0.009 | -0.001 | -0.0004 | -0.001 |
| Black | Unmatched | -0.016*** | 0.0003 | -0.022*** | 0.004 | 0.004 | 0.003 |
| | Matched | 0 | 0 | 0 | 0 | 0 | 0.003 |
| Hispanic | Unmatched | -0.034** | 0.029 | 0.039* | -0.078*** | -0.080*** | -0.07*** |
| | Matched | 0.001 | 0.001 | 0.001 | 0 | 0 | 0 |
| Free and Reduced | Unmatched | -0.012 | -0.024 | -0.002 | 0.047*** | 0.044* | 0.051* |
| | Matched | 0.001 | 0.001 | 0.002 | -0.001 | 0.003 | -0.004 |
| Underweight | Unmatched | -0.010** | 0.002 | -0.021*** | -0.003 | -0.004 | -0.001 |
| | Matched | 0.0003 | 0 | 0.0003 | 0 | 0 | 0 |
| Normal Weight | Unmatched | 0.027 | 0.032 | 0.023 | -0.046** | -0.056* | -0.036 |
| | Matched | -0.002 | -0.002 | -0.004 | -0.001 | -0.007 | 0.001 |
| Overweight | Unmatched | -0.013 | -0.030 | 0.001 | 0.024 | 0.0003 | 0.054** |
| | Matched | 0 | 0 | 0.001 | 0.0002 | -0.001 | 0 |
| Single Mother Prop | Unmatched | -0.044*** | -0.051*** | -0.039*** | 0.053*** | 0.051*** | 0.057*** |
| | Matched | -0.016* | -0.001 | -0.035* | 0.039* | -0.030* | 0.049* |
| High School Prop | Unmatched | 0.023*** | 0.015*** | 0.030*** | 0.052*** | 0.060*** | 0.043*** |
| | Matched | 0.004 | 0.009 | 0.013 | 0.025 | 0.031 | 0.018* |
| Some College Prop | Unmatched | 0.003 | 0.001 | 0.002 | 0.025*** | 0.018*** | 0.033*** |
| | Matched | -0.002 | 0.0002 | -0.004 | 0.022 | -0.021 | -0.023* |
| College Plus Prop | Unmatched | -0.064*** | -0.054*** | -0.073*** | -0.105*** | -0.114*** | -0.095*** |
| | Matched | -0.032 | -0.048* | -0.018 | -0.073 | -0.079 | -0.065* |
| Below Pov. Prop | Unmatched | 0.003 | -0.044* | 0.003 | 0.019*** | 0.024*** | 0.011** |
| | Matched | 0.005 | 0.007 | -0.002 | 0.013* | -0.014* | -0.010* |
| No Vehicle Prop. | Unmatched | -0.007*** | -0.006** | -0.007*** | 0.004*** | 0.005*** | 0.004** |
| | Matched | 0.0002 | 0.001 | -0.002 | 0.001* | -0.002* | -0.0001 |
| Observations | Treated ($N_T$) | 1,468 | 768 | 700 | 617 | 336 | 281 |
| | Untreated ($N_u$) | 10,946 | 5,913 | 5,033 | 4,188 | 2,242 | 1,946 |

Note: *,**,***denote significance at the 0.1, 0.05, 0.01 level, respectively. The treatment variable for urban children is whether they have park exposure in a half mile around their residence. The treatment variable for rural children is whether they have park exposure in three miles around their residence. $N_T$ and $N_u$ are number of individuals in treated group and untreated group, respectively. Mean differences of each matching covariate between those in the untreated group and those in the treated group. We used proportion test for binary variables and t-test for continuous variables.

**Table 3. Average Treatment Effect on Untreated Group (ATU) of the Neighborhood Parks on Children's BMIs**

| | Urban (A Half Mile) | | | Rural (Three Miles) | | |
|---|---|---|---|---|---|---|
| | **All** | **Male** | **Female** | **All** | **Male** | **Female** |
| Three-Year Effect[a] | -0.033 | -0.054 | -0.014 | -0.167*** | -0.0001 | -0.295*** |
| | (0.032) | (0.047) | (0.044) | (0.050) | (0.069) | (0.076) |
| Two-Year Effect | 0.040 | -0.061 | -0.017 | -0.061 | -0.081 | -0.078 |
| | (0.031) | (0.045) | (0.042) | (0.045) | (0.065) | (0.065) |
| One-Year Effect | -0.046 | -0.043 | -0.049 | -0.051 | -0.020 | -0.088 |
| | (0.028) | (0.040) | (0.041) | (0.042) | (0.060) | (0.062) |
| Three-Year Effect within 15 miles[b] | | | | -0.178*** | -0.043 | -0.40*** |
| | | | | (0.057) | (0.074) | (0.097) |
| Observations | | | | | | |
| Treated ($N_T$) | 1,468 | 768 | 700 | 617 | 336 | 281 |
| Untreated ($N_u$) | 10,946 | 5,913 | 5,033 | 4,188 | 2,242 | 1,946 |

Note: The treatment variable for urban children is whether they have park exposure in a half mile around their residence. The treatment variable for rural children is whether they have park exposure in three miles around their residence. $N_T$ and Nu are number of individuals in treated group and untreated group, respectively. ATU is defined as the estimates of average treatment effect on untreated.
Standard errors appear in parenthesis. ***denote significance at the 0.01 level.
a. 3 years effect, 2 years effect and 1 year effect use outcome variables (BMI z-score) for year 2007, 2006 and 2005 respectively.
b. The estimate drops the observations which lived more than 15 miles away with a park for rural children.

**Table 4. Average Treatment Effect on Untreated Group of the Neighborhood Parks on Children's BMIs for Age Subgroups**

| | Urban (A Half Mile) | | Rural (Three Miles) | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Age 5-9 years old | | | | |
| Three-Year Effect | -0.033 | -0.072 | -0.121 | -0.278** |
| | (0.066) | (0.065) | (0.119) | (0.132) |
| Observations | | | | |
| Treated($N_T$) | 382 | 376 | 156 | 131 |
| Untreated ($N_u$) | 2,981 | 2,706 | 1,025 | 967 |
| Age 10-16 years old | | | | |
| Three-Year Effect | -0.099 | 0.051 | -0.119 | -0.141 |
| | (0.068) | (0.057) | (0.089) | (0.095) |
| Observations | | | | |
| Treated($N_T$) | 386 | 324 | 180 | 150 |
| Untreated ($N_u$) | 2,932 | 2,327 | 1,217 | 979 |

Note: Standard errors appear in parenthesis.
*** denote significance at the 0.01 level. $N_T$ and Nu are number of individuals in treated group and untreated group, respectively.

**Table 5. The Estimates of DID Model for New Park Constructed in 2005**

| | Urban | Rural |
|---|---|---|
| | A Half Mile | Three Miles |
| Three-Year Effect | 0.073 | -0.052 |
| | (0.125) | (0.054) |
| Two-Year Effect | 0.076 | -0.014 |
| | (0.120) | (0.042) |
| One-Year Effect | 0.077 | 0.059 |
| | (0.115) | (0.040) |
| Observations | | |
| Treated($N_T$) | 40 | 84 |
| Untreated ($N_u$) | 61 | 206 |

Note: Covariates Matching with three nearest neighbors are applied before DID regression. The treatment group in DID model is these who have newly park exposure on 2005. The untreated group is these who have no park exposure during 2004-2007 $N_T$ and $N_u$ denotes the number of individuals in treated and untreated group. Standard errors appear in parenthesis, which is clustered by block groups.