Journal of Healthy Eating and Active Living
2025, Vol. 5, No. 2, pgs. 161-170

Association Between School Neighborhood Walkability and Adolescent Physical Activity

Brooke E. Wagner[1,2], Zili Zong[3], Cody D. Neshteruk[1,2], and Emily M. D'Agostino[1,2,4,5,6]

[1] Department of Population Health Sciences, Duke University School of Medicine, U.S.A.

[2] Duke Center for Childhood Obesity Research, Duke University School of Medicine, U.S.A.

[3] Department of Biostatistics and Bioinformatics, Duke University, U.S.A.

[4] Department of Orthopaedic Surgery, Duke University School of Medicine, U.S.A.

[5] Duke Clinical Research Institute, Duke University School of Medicine, U.S.A.

[6] Duke Global Health Institute, Duke University School of Medicine, U.S.A.

Abstract

Neighborhood structural factors are associated with greater feasibility of youth active travel and thus, greater levels of physical activity. However, limited prior work has addressed walkability factors specific to the school neighborhood related to adolescent physical activity during the school day. Therefore, the purpose of this study was to examine the relationship between two school neighborhood walkability factors (neighborhood density and neighborhood age) and school-related adolescent moderate-to-vigorous physical activity (MVPA). We analyzed cross-sectional data from the Family Life, Activity, Sun, Health, and Eating (FLASHE) study for 1,183 adolescents ages 12-17 years. Separate linear regression models assessed the association between both school-neighborhood density and school-neighborhood age (i.e., population/housing unit density and age of buildings/units, respectively, within a 400m buffer around school address) and adolescent school-related MVPA, adjusting for age, sex, race/ethnicity, weight status, urban/rural environment and parent MVPA. School-neighborhood density (8.62, 95% CI: 0.70, 16.53) and school-neighborhood age (6.38, 95% CI: -0.29, 13.05) were both positively associated with school-related MVPA, although the neighborhood age-MVPA association observed was not statistically significant. When seeking to improve physical activity among adolescents, school neighborhood structural factors that support physical activity throughout a school day should be considered. Unfortunately, macro-scale environmental features such as these are not easily modified. Thus, these findings should be used to inform additional research related to school-neighborhood walkability and adolescent participation in physical activity.
Keywords: Adolescent Health, Physical activity, Walkability, School-Neighborhood, Moderate-to-vigorous physical activity

Routine youth physical activity (PA) supports healthy habits early in life, with lasting benefits into adulthood, including protection against cardiometabolic risk factors like high blood pressure, obesity, and diabetes (World Health Organization, 2024). The World Health Organization (WHO) recommends that youth ages 6-17 years engage in 60 minutes of moderate-to-vigorous PA (MVPA) every day (WHO, 2004). However, steep declines in MVPA are observed in adolescence, particularly among racial/ethnic minorities, resulting in only 7% of US youth ages 12-15 years and 5% of US youth ages 16-19 years meeting PA guidelines (Rodriguez-Ayllon et al., 2019; Allison et al., 2007; Armstrong et al., 2018; Belcher et al., 2010; Katzmarzyk et al., 2018). This presents a critical need to identify factors that may improve adolescent MVPA.

The neighborhood built environment around the home can play an important role in promoting PA among youth. In particular, factors impacting walkability and greater diversity of land-use (i.e., the broad mix of residential, commercial, and office spaces within a walkable distance) of a neighborhood have been shown to be positively associated with PA and active transportation (Ding et al., 2011; Kligerman et al., 2007; Frank et al., 2007). Residential (population and housing) density and neighborhood age are two important and widely used indicators of neighborhood walkability among both youth and adults (Berrigan & Troiano, 2002; Boer et al., 2007; Smith et al., 2008; Kowaleski-Jones et al., 2017). Greater neighborhood residential density may increase walking patterns if more people are seen walking throughout the neighborhood, and may coincide with greater land use mix and more destinations within walking distance. Additionally, older neighborhoods promote walkability as they were more likely to have been designed with a pedestrian friendly focus with more features like sidewalks, interconnected street networks, and more commercial areas within close proximity (i.e., land use diversity) (Molina-Garcia, Garcia-Masso, et al., 2019).

While the diversity of land use and walkability factors around the home neighborhood environments show promising benefits for PA behaviors among adolescents, especially on weekends, it is less clear if environmental factors around the school neighborhood play a similar role (Loh et al., 2020). Given the amount of time youth spend at school, and also traveling each day to and from school, the built environment around the school may play an important role in supporting and promoting PA among this age group especially on school days. One prior study suggests that the school neighborhood environment may be associated with youth MVPA outside of school hours, while land use mix was negatively associated with school day MVPA. Additional studies have found that the built environment and walkability of the area surrounding the school (measured through neighborhood density, street intersection density, land use mix, and other micro-scale environment factors such as streetscape features) may specifically promote active transportation to and from school and thus overall PA (Braza et al., 2004; Molina-Garcia, Campos et al., 2020; Panter et al., 2010; Carlson et al., 2014; Davidson et al., 2008; Faulkner et al., 2013; Lubans et al., 2011). While transportation to and from school may play a large role in youth PA during school days, additional opportunities for engagement include physical education (PE) and recess which may also be impacted by the built environment around the school. Still, limited prior work has assessed how the built environment and walkability may be associated with school time PA overall.

Therefore, this study aimed to examine the relationship between two school-neighborhood built environment factors associated with walkability (neighborhood density and neighborhood age) and total time per week adolescents spent engaging in school-related MVPA, including active transportation, recess, physical education, and other PA opportunities throughout a school day. With a more nuanced understanding of the relationship between environmental factors and PA beyond the immediate home environment, this work can inform future youth PA promotion initiatives related to city planning, land use, and community design around school environments.

Methods

We conducted a cross-sectional analysis of publicly available data from The Family Life, Activity, Sun, Health, and Eating (FLASHE) study, conducted by the National Cancer Institute (NCI) (NCI, 2020a). The sample was drawn from a Consumer Opinion Panel using a balanced sampling method so that the sample demographic characteristics closely match with the general US population (including gender, race/ethnicity, household income and size, and census division (NCI, 2018). The FLASHE Study was approved by Westat, Inc., and NCI Special Studies Institutional Review Boards. Adolescents ages 12 to 17 years old with complete demographic information (sex, age, height and weight, and race/ethnicity), school environments, and PA measures were included (see Supplemental Figure 1 for more data collection detail).

Measures

The primary exposures were two school-neighborhood walkability factors: school-neighborhood density (population/housing unit density) and school-neighborhood age (age of buildings/units) within a 400m buffer around each participant's school address. Neighborhood information and youth residential addresses were Geocoded by the FLASHE study to develop the neighborhood and contextual variables to be linked to youth survey data. School-neighborhood density and school-neighborhood age were derived using principal component analysis from all census tracts in the U.S. (Hoehner et al., 2011). Higher values for each factor are associated with greater density and older neighborhoods, and are hypothesized to correspond with more conducive walking environments Additional information on the methods used to estimate the buffer zone and construct these variables are described in detail in the FLASHE data user technical report.

The primary outcome for this study was adolescent school-related moderate to vigorous PA, a summary measure of all items reflecting PA during school hours (PE, recess, lunch time activity, and active transportation to and from school) (NCI, 2020b). PA was self-reported using the Youth Activity Profile, and MVPA was obtained by weighting individual items for school-related PA using a previously derived calibration procedure, which allows raw composite scores of each activity type to be converted to an estimate of relative time in minutes spent per day in school-related MVPA.

Statistical Analysis

Descriptive statistics including means and standard deviations for continuous variables and frequencies and percentages for categorical variables were calculated to describe the sample and exposure variables. Chi-squared tests were used to compare the distribution of categorical variables (age, sex, race/ethnicity, weight status [based on age- and sex-adjusted body mass index], and urban/rural environment) across school-neighborhood walkability factors (neighborhood density and neighborhood age).

Cut points with roughly equal proportions of the populations in each subgroup for all US census tracts were calculated and applied to each school-neighborhood walkability factor at school locations to yield tertiles (low, medium and high). Analysis of variance (ANOVA) was used to compare means of MVPA across school-neighborhood walkability factor tertiles. Adjusted models included adolescents' demographics (age, sex, race/ethnicity, weight status and urban/rural environment) and parent MVPA (collected by self-report, and included due to the well-documented association between parent and child PA),[17] as covariates. A significance level of 0.05 was used for all analyses. All statistical analyses were conducted using R Studio 1.4.1103.

Results

The total number of participants who had data on exposure covariates and outcomes was 1,183. The sample included approximately the same proportion of males and females (50.1% and 49.9%, respectively). Most adolescents were non-Hispanic White (64.8%) and had either underweight or healthy weight (73.1%). Most adolescents attended school in the suburbs (43.1%) or cities (27.6%).

Journal of Healthy Eating and Active Living
2025, Vol. 5, No. 2, pgs. 161-170

The average (mean ±SD) weekly minutes of school-related MVPA was 289 ±53.0 minutes per week. Additional characteristics of the sample can be found in Supplemental Table 1.

The descriptive distribution of demographic characteristics and PA of adolescents across tertiles of school-neighborhood density and school-neighborhood age are detailed in Supplemental Table 1. Differences in the distribution of race and ethnicity were observed for both school-neighborhood density and age, where the majority of participants in low and medium levels of school-neighborhood density were White, while the higher density school-neighborhoods were evenly divided between White and non-white participants (see Supplemental Table 1). Additionally, differences were observed for the distribution of urban and rural environments of school for both neighborhood density and neighborhood age. No differences in school-related MVPA were found between tertiles of neighborhood density or neighborhood age.

In adjusted models shown in Figure 1, school-neighborhood density (8.62, 95% CI: 0.70, 16.53) was positively associated with school-related MVPA, such that adolescents in the highest tertiles of school-neighborhood density and school-neighborhood age had higher school-related MVPA compared to adolescents in the lowest tertiles. School-neighborhood age also showed a positive relationship with school-related MVPA, although the association was not statistically significant (6.38, 95% CI: -0.29, 13.05).

Commented [ED1]: I think we should push back here and keep the original lanugage… I offered some language we can work from in the response letter that was "handed down" to me from an expert epi colleague at BUSPH, and has worked on prior submissions when I knew overall the editors were in favor of publication so I felt safe so to speak… wondering your and Cody's thoughts…

Suggested a slight modification from what we had before (see edit).

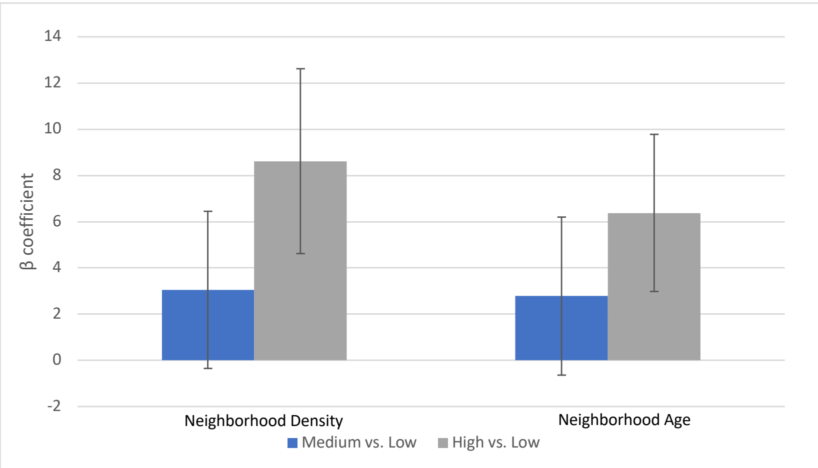

Figure 1. β coefficients from linear regression models of the relationship between adolescent school-related MVPA and neighborhood factors, comparing medium vs. low tertiles, and high vs. low tertiles and adjusted for adolescent demographics and parent MVPA (n=627).

Discussion

This study drew data from the FLASHE study to examine the relationship between school-neighborhood walkability factors and school-related adolescent MVPA. Students attending schools in high density (i.e., high residential density and high use of public transit and walking or biking) and neighborhoods with older age had higher school-related MVPA compared to those attending school in neighborhoods with low density and younger age. These findings support those from California Public Schools, in which the neighborhood density around the school was associated with adolescent PA, though neighborhood age was not assessed. Contrary to our findings, among a small sample of 417 adolescents in Australia, the walkability around school-neighborhoods (based on street intersections, density, and land use mix) was not associated with overall MVPA on weekdays for adolescents, although associations were found with other school built environment factors (i.e., number of parks, park areas, and trails). Differences in these findings compared to our study results may be related to the specific school-neighborhood built environment factors that were assessed, making it difficult to directly compare results.

Our current findings also mirror those assessing residential neighborhood density and age (as opposed to school neighborhoods), where neighborhood density and age were positively associated with adolescent PA behavior. Previous studies have suggested that youth are more likely to walk or bike to school rather than take public transportation if they live in neighborhoods with decreased proximity between school and homes (which is often the case in older neighborhoods), and when walkability is greater surrounding schools (Christiansen et al., 2014). The school-related MVPA questions in our current study included the number of days that youth walk or bike to/from school, thus we may conclude that denser and older school-neighborhoods improve walkability to allow for more active transportation and ultimately greater levels of adolescent PA as supported by previous findings (Larouche et al., 2014). Importantly, Smith and colleagues found and inverse association between neighborhood age (as a proxy for land-use diversity) and walkability related risk of obesity among adults. These findings highlight the importance of considering school neighborhood structural environments when designing health initiatives to promote active travel to school and access to PA among youth populations, particularly for adolescents living in urban settings.

This study strengthens our understanding of the relationship between school-neighborhood walkability and adolescent PA during the school day. This study also included the use of a national sample, a validated measure for PA, data driven identification of school-neighborhood walkability factors, and analyses that accounted for the relationship between multi-level factors and youth PA. However, several limitations need acknowledgement. Although the study sample was a nationwide sample, the demographics are not nationally representative, limiting our ability to generalize findings to the wider U.S. adolescent population. Additionally, this study was cross-sectional and limited by sample size. Future research should examine these relationships over time and with larger samples to provide more precise and longitudinal estimates. Also, this study examined just two measures of the school-neighborhood environment. Other school-neighborhood walkability factors may be important predictors of youth MVPA, including proximity and density of walking/biking paths, greenspace and parks, recreation sites and quality of play equipment, and tree cover (Heath et al., 2012; Sallis et al., 2012). Beyond walkability, additional factors within the school like types of equipment offered, green space availability, facility types, and amount of school-based PA programing offered, were not available in the FLASHE dataset to include in the analysis, limiting our ability to understand how other important factors might influence school day PA for youth. Further research should investigate the association between additional school-neighborhood walkability and school environment factors and adolescent MVPA throughout the school day. In addition, data collected from FLASHE were mainly self-reported, although estimated time spent in MVPA drawing from FLASHE surveys were statistically equivalent to accelerometer-measured estimates for both school-based PA in a follow-up study (Saint-Maurice et al., 2017).

Conclusion

Routine youth PA has lasting cardiovascular and mental health benefits tracking into adulthood, although only 20% of U.S. adolescents meet the recommended guidelines of at least 60 minutes of MVPA per day. This study examined the relationship between both school-neighborhood walkability and school-related adolescent PA. Students attending schools in neighborhoods with high density and older neighborhood age had higher school-related MVPA compared to those attending school in neighborhoods with low density and younger age. These findings can be used to support programming and policies to increase adolescent PA participation and downstream cardiovascular and mental health benefits across the lifespan.

Corresponding author

Brooke E. Wagner

215 Morris St, Duke University

Durham, NC 27701

brooke.wagner@duke.edu

(989) 600-2496

- Brooke E. Wagner: **0000-0002-8969-3653**
- Zili Zong: 0000-0002-6828-2388
- Cody D. Neshteruk: 0000-0002-0516-6873
- Emily M. D'Agostino: 0000-0002-1631-0279

Author Contributions

Conceptualization: all authors contributed equally; Data curation: E. M. D. and Z. Z.; Formal analysis: E. M. D. and Z. Z.; Methodology: E. M. D., Z. Z., and C. D. N.; Supervision: E. M. D. and C. D. N.; Writing – original draft: Z. Z. and B. E. W.; Writing – review & editing: all authors contributed equally.

Acknowledgements

None.

Conflicts of interest

The authors have no conflicts of interest to disclose.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Allison, K. R., Adlaf, E. M., Dwyer, J. J., Lysy, D. C., & Irving, H. M. (2007). The decline in physical activity among adolescent students: a cross-national comparison. *Canadian journal of public health = Revue canadienne de sante publique*. 98(2):97-100.

Armstrong, S., Wong, C. A., Perrin, E., Page, S., Sibley, L., & Skinner, A. (2018). Association of Physical Activity With Income, Race/Ethnicity, and Sex Among Adolescents and Young Adults in the United States: Findings From the National Health and Nutrition Examination Survey, 2007-2016. *JAMA pediatrics*. 172(8):732-740. doi:10.1001/jamapediatrics.2018.1273

Belcher, B. R., Berrigan, D., Dodd, K. W., Emken, B. A., Chou, C. P., & Spruijt-Metz, D. (2010, December). Physical activity in US youth: effect of race/ethnicity, age, gender, and weight status. *Med Sci Sports Exerc*. Dec 2010;42(12):2211-21. doi:10.1249/MSS.0b013e3181e1fba9

Berrigan, D. & Troiano, R. P. (2022, August). The association between urban form and physical activity in U.S. adults. *Am J Prev Med*. 23(2 Suppl):74-9. doi:10.1016/s0749-3797(02)00476-2

Boer R, Zheng Y, Overton A, Ridgeway GK, Cohen DA. (2007, April). Neighborhood design and walking trips in ten U.S. metropolitan areas. *Am J Prev Med*. 32(4):298-304. doi:10.1016/j.amepre.2006.12.012

Braza, M., Shoemaker, W., & Seeley, A. (2004). Neighborhood design and rates of walking and biking to elementary school in 34 California communities. *Am J Health Promot*. 19(2):128-36. doi:10.4278/0890-1171-19.2.128

Carlson, J. A., Sallis, J. F., Kerr, J., et al. (2014). Built environment characteristics and parent active transportation are associated with active travel to school in youth age 12-15. *Br J Sports Med.* 48(22):1634-1639. doi: 10.1136/bjsports-2013-093101

Christiansen, L. B., Toftager, M., Schipperijn, J., Ersboll, A. K., Giles-Corti, B., & Troelsen, J. (2014). School site walkability and active school transport - association, mediation and moderation. *J Transp Geogr*. 34:7-15.

Davison, K. K., Werder, J. L., & Lawson, C. T. (2008, July). Children's active commuting to school: current knowledge and future directions. *Prev Chronic Dis*. 5(3):A100.

Ding, D., Sallis, J. F., Kerr, J., Lee, S., & Rosenberg, D. E. (2011, October). Neighborhood environment and physical activity among youth a review. *Am J Prev Med*. 41(4):442-55. doi:10.1016/j.amepre.2011.06.036

Faulkner, G., Stone, M., Buliung, R., Wong, B., & Mitra, R. (2013, December 11). School travel and children's physical activity: a cross-sectional study examining the influence of distance. *BMC Public Health*. 13:1166. doi:10.1186/1471-2458-13-1166

Frank, L., Kerr, J., Chapman, J., & Sallis, J. (2007). Urban form relationships with walk trip frequency and distance among youth. *Am J Health Promot*. 21(4 Suppl):305-11. doi:10.4278/0890-1171-21.4s.305

Heath, G. W., Parra, D. C., Sarmiento, O. L., et al. (2012). Evidence-based intervention in physical activity: lessons from around the world. *The Lancet*. 380(9838):272-281. doi:10.1016/s0140-6736(12)60816-2

Hoehner, C. M., Handy, S. L., Yan, Y., Blair, S. N., & Berrigan, D. (2011, December). Association between neighborhood walkability, cardiorespiratory fitness and body-mass index. *Soc Sci Med*. 73(12):1707-16. doi:10.1016/j.socscimed.2011.09.032

Katzmarzyk, P. T, Denstel, K. D., Beals, K., et al. (2018). Results from the United States 2018 report card on physical activity for children and youth. 15(s2):S422-S424.

Kligerman, M., Sallis, J. F., Ryan, S., Frank, L. D., & Nader, P. R. (2007). Association of neighborhood design and recreation environment variables with physical activity and body mass index in adolescents. *Am J Health Promot*. 21(4):274-7. doi:10.4278/0890-1171-21.4.274

Kowaleski-Jones, L., Fan, J. X., Wen, M., Hanson, H. (2017, September). Neighborhood Context and Youth Physical Activity: Differential Associations by Gender and Age. *Am J Health Promot*. 31(5):426-434. doi:10.1177/0890117116667353

Larouche, R., Saunders, T. J., Faulkner, G., Colley, R., & Tremblay, M. (2014, January). Associations between active school transport and physical activity, body composition, and cardiovascular fitness: a systematic review of 68 studies. *J Phys Act Health*. 11(1):206-27. doi:10.1123/jpah.2011-0345

Loh, V. H., Veitch, J., Salmon, J., et al. (2020, May). Residential vs school neighborhoods: Associations with physical activity among adolescents. *Health Place*. 63:102328. doi:10.1016/j.healthplace.2020.102328

Lubans, D. R., Boreham, C. A., Kelly, P., & Foster, C. E. (2011, January 26). The relationship between active travel to school and health-related fitness in children and adolescents: a systematic review. *Int J Behav Nutr Phys Act*. 8:5. doi:10.1186/1479-5868-8-5

Molina-García, J., Campos, S., García-Massó, X., et al. (2020). Different neighborhood walkability indexes for active commuting to school are necessary for urban and rural children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity*. 17(1)doi:10.1186/s12966-020-01028-019.

Molina-Garcia, J., Garcia-Masso, X., Estevan, I., Queralt, A. (2019). Built environment, psychosocial factors and active commuting to school in adolescents: Clustering a self-organizing map analysis. *Int J Environ Res Public Health.* 16(1):83. doi: 10.3390/ijerph16010083

National Cancer Institute. (March, 2018). Family Life, Activity, Sun, Health, and Eating (FLASHE) GeoFLASHE Methods Report. Retrieved August 15, 2021 from https://cancercontrol.cancer.gov/sites/default/files/2020-06/geoflashe-methods-report-nci.pdf

National Cancer Institute. (2020a). 2014 Family Life, Activity, Sun, Health and Eating (FLASHE) Survey Data. Rockville, MD: U.S. Department of Health and Human Services, National Cancer Institute. Retrieved August 15, 2021 from http://cancercontrol.cancer.gov/brp/hbrb/flashe.html

National Cancer Institute. (2020b). Guide for Data Users: The Family Life, Activity, Sun, Health, and Eating Study (FLASHE). Retrieved August 15, 2021 from https://cancercontrol.cancer.gov/sites/default/files/2020-06/flashe-data-users-guide.pdf.

Panter, J. R., Jones, A. P., Van Sluijs, E. M. F., & Griffin, S. J. (2010). Neighborhood, route and school environments and children's active commuting. *Am J Prev Med.* 38(3). doi: 10.1016/j.amepre.2009.10.040

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., et al. (2019). Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine*. 2019/09/01 2019;49(9):1383-1410. doi:10.1007/s40279-019-01099-5

Saint-Maurice, P. F., Kim, Y., Hibbing, P., Oh, A. Y., Perna, F. M., & Welk, G. J. (2017). Calibration and Validation of the Youth Activity Profile: The FLASHE Study. *American Journal of Preventive Medicine*. 52(6):880-887. doi:10.1016/j.amepre.2016.12.01031.

Sallis, J. F., Floyd, M. F., Rodriguez, D. A., & Saelens, B. E. (2012, February 7). Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation*. 125(5):729-37. doi:10.1161/CIRCULATIONAHA.110.969022

Smith, K. R., Brown, B. B., Yamada, I., Kowaleski-Jones, L., Zick, C. D., Fan, J. X. (2008, September). Walkability and body mass index density, design, and new diversity measures. *Am J Prev Med*. 35(3):237-44. doi:10.1016/j.amepre.2008.05.028

World Health Organization. (2004, May 26). *Global Strategy on Diet, Physical Activity and Health: What can be done to fight the childhood obesity epidemic?* https://www.who.int/publications/i/item/9241592222

World Health Organization. (2024, June 26). *Physical activity*. World Health Organization. Accessed June 3, 2024. https://www.who.int/news-room/fact-sheets/detail/physical-activity