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Pedalcyclist Fatalities and Socioeconomic Status: A Spatial Epidemiological Study of the United States, 2011–2013

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Abstract

Bicycling is a popular recreation activity and mode of transportation among the American workforce. While safety standards are key factors in reducing risk for a cycling fatality, contextual factors also play a role. State-level data for this study were retrieved from the U.S. Census Bureau, the League of American Bicyclists, and the National Highway Traffic Safety Administration. Trend analysis was conducted via ANOVA and the trajectory of the pedalcyclist fatality rate (PFR) from 2011 to 2013 was determined. Linear regression was conducted and the influence of socioeconomic variables on PFR between 2011 and 2013 was determined. The average state-level PFR increased between 2011 and 2013; however, the trend was not statistically significant. Regression analysis showed that socioeconomic variables were significant predictors of PFR, after controlling for relevant covariates. To improve cycling safety, states should not only adopt legislation and infrastructure that support cycling but also consider implementing innovative road-safety educational programs in resource-deprived areas.

KEYWORDS: pedalcyclist fatalities; socioeconomic status; bicycle friendliness

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Cycling is an important way of improving physical activity, engaging in leisure recreation, limiting transportation-related greenhouse emissions, and providing economic benefits in the United States (Cavill & Davis, 2003; Shields et al., 2017). Cycling has physical health benefits for individuals and communities; however, pedalcyclist-related accidents contribute to many road-related accidents annually. Fatalities often result from such accidents (Vargo, Gerhardstein, Whitfield, & Wendel, 2015). Pedalcyclist accidents typically result in emergency service requests and in the United States cause 900 deaths, 23,000 hospital admissions, 580,000 emergency department visits, and more than 1.2 million physician visits per year (National Center for Statistics and Analysis [NCSA], 2016; Thompson & Rivara, 2001).

Literature Review

History of Road and Cycling Safety in the United States

During the 1970s, as rising oil prices drove up fuel costs for consumers and created interest in cleaner commuting, cycling gained mainstream popularity (McClean, 2012). Environmental supports were rarely in place municipally, and minimal research had focused on cycling fatalities (Mitchell & Bambach, 2015). Cyclists embracing the practice for both sport and travel were often unaware of the risk factors for a pedalcyclist accident, including road design and engineering, traffic law enforcement, driver and cyclist behavior, helmet use, and traffic volume (Vargo et al., 2015). Other factors affecting the risk for a pedalcyclist fatality, including inclement weather, unlit streets, time of day, intoxication, speed of the cyclist, and other cyclists involved, were also not commonly publicized (Kim, Kim, Ulfarsson, & Porrello, 2007).

Since 1973, the cyclist mortality rate has decreased overall due to the mandatory standards put in place for all bicyclists by the U.S. Consumer Product Safety Commission (Rodgers, 1992; Vargo et al., 2015); however, the risk for a pedalcyclist accident has not been eliminated, largely due to environmental factors. According to a survey conducted by the National Highway Traffic Safety Administration (2014), 88% of cyclists felt threatened by motorists while riding their bicycle, and 37% felt that the built environment, specifically poor roadways and walkways, hindered personal safety. The perceived risks correspond to the three pillars of safety in Schepers, Hagenzieker, Methorst, van Wee, and Wedman's (2014) proposed model of road safety: infrastructure, road users, and the modes of transportation they use.

Modifiable and Nonmodifiable Risk Factors

Currently, more than half of the cyclist population are males between the ages of 25 and 64 (Pucher, Buehler, & Seinen, 2011). The highest rates of accident fatalities affected cyclists between 20 and 54 years of age (Mitchell & Bambach, 2015; NCSA, 2016), and of these fatalities, only 26% of cyclists were wearing helmets (Gaudet et al., 2015). In a 2003 Bureau of Transportation Statistics study, recreational use and health were primary reasons for cycling, making up 78% of all cycling trips (U.S. Department of Transportation, Federal Highway Administration, 2002).

Participation in some risky behaviors may also increase the likelihood of a pedalcyclist fatality. According to one study, 35% of individuals who died in a pedalcyclist accident had increased blood alcohol concentrations (NCSA, 2016). Studies have shown that alcohol, as well as the use of illicit drugs, was detected in 25% of cycling accidents (Donatelle & Ketcham, 2013).

Socioeconomic status (SES) can affect pedalcyclist fatalities in several ways, as well (American Psychological Association, 2016). Residents with lower income and lower educational attainment experience more injuries compared to any other group. SES has also been shown to be associated with the severity of cycling injuries and the likelihood of a motor-vehicle collision among adolescents (Embree et al., 2016). SES has the power to limit the capacity of individuals to mitigate modifiable risk factors for a pedalcyclist fatality. Individuals with low SES may struggle to afford protective equipment for riding, such as a helmet and pads. Less educated persons may have limited knowledge of the harm of unhealthy behavior, such as using alcohol or drugs while cycling, and therefore exhibit less motivation to adopt healthy behaviors (Pampel, Krueger, & Denney, 2010). Pedalcyclist fatalities may, therefore, be elevated in areas characterized by socioeconomic deprivation.

This paper extends the results of previous studies, such as Embree et al.'s (2016) study, Pampel et al.'s (2010) study, and Gaudet et al.'s (2015) study, by (a) providing a nationally representative study and (b) empirically examining the relationship between socioeconomic characteristics and pedalcyclist fatalities both spatially and temporally. Therefore, the purpose of this study was (1) to evaluate the linear growth of the pedalcyclist fatality rate (PFR) at the state level in the United States between 2011 and 2013, (2) to examine state-level changes in pedalcyclist fatalities via geographic information systems, and (3) to determine the effect of state-level SES on state-level pedalcyclist fatalities. We consider states in this study, as states provide (a) a well-defined context for examining population health, (b) a vehicle for policy implementation affecting large numbers of individuals, and (c) an established unit of analysis used in other epidemiological studies of road safety (Traynor, 2009).

Method

Data Collection

State-level secondary data for this spatiotemporal ecological study were downloaded from several sources. The main study variables in this study were pedalcyclist fatalities, poverty, and educational attainment. First, annual pedalcyclist fatalities per 1,000,000 population were downloaded for every state (n = 50) in the United States between 2011 and 2013 (variable names: PFR2011, PFR2012, and PFR2013) from the National Highway Traffic Safety Administration (2013, 2014, 2015). Second, annual poverty rates at the state level (variable names: POV2011, POV2012, and POV2013), measured as the percentage of people in each state living in poverty, were downloaded for 2011 to 2013 (U.S. Census Bureau, 2018). Third, educational attainment data—measured as the percentage of state residents, 18 years or older, without a high school education (EDUC2011, EDUC2012, EDUC2013)—were retrieved for 2011 to 2013 (U.S. Census Bureau, 2018).

Three state-level covariates were also considered in this study: the extent of bicycling as a mode of transportation (CYC2011, CYC2012, CYC2013), the extent to which states tried to ensure bicyclist safety (FR2011, FR2012, FR2013), and total population estimates (POP2011, POP2012, POP2013). Transportation via bicycling in 2011, 2012, and 2013 was measured as the percentage of the state population who used a bicycle to commute to work (U.S. Census Bureau, 2018); this variable was included as a covariate, as the "safety in numbers" hypothesis (Fyhri, Sundfor, Bjornskau, & Laureshyn, 2017) would suggest that states with more pedalcyclists should have fewer pedalcyclist fatalities. State rankings in 2011, 2012, and 2013 for "bicycle friendliness" were retrieved from the League of American Bicyclists (LAB, 2017). We used these to measure how safe the environment was for bicycling. The LAB annually collects data from each state's Department of Transportation in the areas of safety encouragement, infrastructure, legislation, policies, and planning as they relate to bicycling, to determine state-level bicycle friendliness. Additional information regarding data collection and calculation of state rankings for bicycle friendliness have been published elsewhere (LAB, 2017). Last, state-level population estimates for 2011, 2012, and 2013 were retrieved from the U.S. Census Bureau (2018).

Data Analysis

The data sets were joined and analyzed using R, the Project for Statistical Computing (R Core Team, 2018). First, descriptive statistics, such as means and standard deviations, were calculated for each variable across each year of the study by United States region (i.e., West, South, Midwest, and Northeast). Choropleth mapping techniques were used within the QGIS environment (QGIS Development Team, 2009), and this showed geographic disparities in pedalcyclist fatalities at the state level. The spatial analysis was executed, and the average annual change in pedalcyclist fatalities between 2011 and 2013 for each state was calculated.

Linear increases or decreases of the average state-level PFR over the 3-year study were determined through linear trend analysis via analysis of variance (ANOVA; Pinhas, Tzelgov, & Ganor-Stern, 2012). Owing to departures from normality for each year of PFR data, log transformations were applied to each variable (González-Velasco, 2010) and the ANOVA procedure was bootstrapped with 1,000 resamples (Mooney & Duval, 1993).

Also, the effect of SES—measured in this study as the extent of poverty and educational attainment—on pedalcyclist fatalities were determined through three ordinary least squares regression models estimated for each year of the study. Each regression model was bootstrapped with 1,000 resamples, which enhanced the precision of estimates (Freedman, 1981). The dependent variable in each model, PFR, was regressed on poverty rates and educational attainment, as well as the covariates of bicycle friendliness, popularity of bicycling, and total population estimates.

Results

Table 1 shows the results of the descriptive analysis. An upward trend in the average state-level PFR occurred in the United States between 2011 and 2013, with a rate (based on the arithmetic mean of all states) of 1.65/1,000,000 in 2011, 1.75/1,000,000 in 2012, and 1.79/1,000,000 in 2013, although the trend was not statistically significant, $F(1, 147) = 0.534$, $p = 0.466$. Some variation was observed among certain states. In particular, based on a calculation of the average annual change in PFR, Oregon exhibited a 1.56/1,000,000 decline in PFR, while Oklahoma exhibited a 1.56 increase in PFR. Figure 1 illustrates the variability.

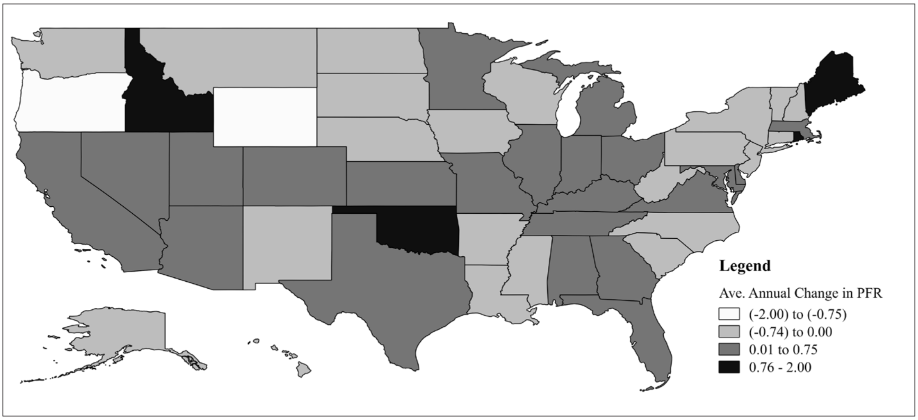

Figure 1. Average annual change in each state's pedalcyclist fatality rate between 2011 and 2013.

Table 1
Means and Standard Deviations of State-Level Variables Aggregated Into United States Regions

	West (n = 13)		South (n = 16)		Midwest (n = 12)		Northeast (n = 9)	
Variable	***M***	**(*SD*)**	***M***	**(*SD*)**	***M***	**(*SD*)**	***M***	**(*SD*)**
PFR2011	1.98	(1.06)	1.75	(1.72)	1.41	(0.64)	1.30	(1.25)
PFR2012	1.79	(1.01)	2.32	(1.63)	1.30	(0.92)	1.24	(0.87)
PFR2013	1.93	(1.22)	2.04	(1.60)	1.40	(0.88)	1.68	(1.11)
CYC2011	1.04	(0.42)	0.23	(0.14)	0.48	(0.15)	0.46	(0.16)
CYC2012	1.07	(0.44)	0.24	(0.14)	0.53	(0.18)	0.47	(0.18)
CYC2013	1.08	(0.44)	0.26	(0.17)	0.51	(0.16)	0.49	(0.18)
FR2011	25.53	(14.40)	31.50	(13.75)	23.83	(16.21)	17.22	(11.22)
FR2012	23.38	(16.11)	30.06	(13.03)	26.25	(15.28)	19.44	(13.48)
FR2013	22.69	(16.37)	29.25	(12.80)	27.92	(16.46)	19.67	(11.48)
POV2011	14.58	(3.22)	15.99	(2.97)	13.14	(2.32)	11.86	(2.39)
POV2012	13.87	(3.27)	16.81	(3.30)	12.85	(1.88)	11.97	(2.75)
POV2013	13.61	(4.30)	16.68	(3.92)	13.44	(2.08)	10.49	(3.37)
EDUC2011	16.75	(3.66)	17.98	(2.23)	14.56	(2.57)	12.78	(1.62)
EDUC2012	16.33	(3.53)	17.34	(2.18)	14.24	(2.54)	12.39	(1.52)
EDUC2013	16.00	(3.29)	16.68	(2.22)	13.91	(2.47)	12.17	(1.31)
POP2011	5.484	(9.678)	7.054	(6.326)	5.562	(4.071)	6.123	(6.443)
POP2012	5.554	(9.770)	7.125	(6.430)	5.578	(4.071)	6.150	(6.474)
POP2013	5.601	(9.857)	7.212	(6.535)	5.595	(4.071)	6.174	(6.503)

Note. PFR = pedalcyclist fatality rate; CYC = percentage of commuters using bicycles; FR = bicycle friendliness ratings; POV = percentage living in poverty; EDUC = percentage of adults without a high school diploma; POP = population estimates in millions.

Table 2 shows the results of the regression analysis. In 2011, the overall model was statistically significant, $F(5, 45) = 46.04$, $p < 0.001$, $R^2 = 0.84$. Results showed that in 2011 states with higher percentages of residents without a high school education had a higher PFR. In 2012, the overall model was statistically significant, $F(5, 45) = 64.69$, $p < 0.001$, $R^2 = 0.89$. Specifically, results showed that states with higher rates of poverty had a higher PFR. In 2013, the overall model was also statistically significant, $F(5, 45) = 55.11$, $p < 0.001$, $R^2 = 0.86$. Like 2011, results from the 2013 model showed that states with higher percentages of residents without a high school education had a higher PFR.

Table 2
Unstandardized Beta Coefficients for the Prediction of Pedalcyclist Fatality Rates at the State Level in 2011, 2012, and 2013 (n = 50)

	PFR2011[a, b]		PFR2012[a, b]		PFR2013[a, b]	
Variable	**β**	**(*SE*)**	**β**	**(*SE*)**	**β**	**(*SE*)**
Bicycle Friendliness	−0.01	(0.01)	0.08	(0.08)	−0.01	(0.01)
Cycling Commuters	0.32	(0.15)*	0.19	(0.14)	0.01	(0.14)
Total Population	0.01	(0.00)*	0.01	(0.00)*	0.01	(0.00)*
Poverty	−0.03	(0.03)	0.05	(0.02)*	0.01	(0.02)
Education	0.07	(0.03)*	-0.04	(0.12)	0.06	(0.02)*

Note. PFR = pedalcyclist fatality rate.

[a]PFR data were $\log_{10}$ transformed. [b]All unstandardized beta coefficients were bootstrapped with 1,000 resamples.

$^*p < 0.05$.

Discussion

Review of Findings

The findings from this study suggest that states with higher poverty rates and lower educational attainment might share certain characteristics that contribute to more frequent pedalcyclist fatalities. The extant cycling literature suggests multiple factors that might be relevant to this study. In a systematic review, Embree et al. (2016) found that cycling injury was associated with lower SES and with riding in rural areas among adolescents. In our study, we found the greatest increase in PFR in Oklahoma, the same state that exhibited the greatest increase in poverty across the study period. Given the rural nature of much of Oklahoma, our findings seem to reflect the general patterns outlined in the Embree et al. study.

Evidence suggests that urban deprivation might also be associated with increased cycling injuries. In a study of 162 census tracts throughout Austin, Texas, Yu (2014) discovered that areas with high poverty rates featured a greater than average number of cycling trips and a higher number of cycling crashes. Perhaps some of this variation relates to the reasons why individuals choose to travel via bicycle. It is possible that people living in poor areas are more likely to cycle as a means of employment-related transportation, yet their neighborhoods might not provide them with a safe environment for doing so (Yu, 2014). Indeed, the percentage share of utilitarian bicycle commuters has been shown to be 4 times higher in urban areas than in rural areas (Pucher et al., 2011). While the percentage of individuals who use cycling as a mode of transport for any purpose (i.e., for utility and for recreation) is about a third higher in urban areas, inversely the proportion of recreational cyclists tends to be higher in rural areas (Pucher et al., 2011). Taken along with Embree et al.'s (2016) findings, these facts suggest that those who use cycling more for utilitarian means might be at substantial risk for injury or fatality, though specific risks might differ by level of urbanity or rurality.

Additionally, in view of Schepers et al.'s (2014) model of road safety, general neighborhood or area quality—in rural and urban areas—might contribute to cycling fatalities. Edwards, Green, Lachowycz, Grundy, and Roberts (2008) used the Index of Multiple Deprivation (which considers the variables of income, employment, health deprivation and disability, education skills and training, barriers to housing, crime, and living environment) and revealed that cyclists in areas of England with increased area deprivation were at 2.6 times greater risk for injury; furthermore, there were significantly steeper deprivation gradients based on settlement type, specifically in town/fringe and in village locations as compared with urban areas. In other words, individuals who reside in economically deprived areas and in those that lack resources and infrastructure (e.g., dedicated biking lanes, parks, or an established cycling culture) are at greater risk for serious injury. Indeed, Shields et al. (2017) showed that infrastructure—adequate bike lanes and appropriate lighting—are significant safety concerns.

Another specific risk factor might be the design of the neighborhoods. In a study of all road users injured over a 5-year span in a large urban area, Morency, Gauvin, Plante, Fournier, and Morency (2012) found significantly more injured cyclists in the poorest rather than the richest census tracts, though neighborhood road design had a mediating effect. Specifically, they found that if the number of four-way intersections in poorer census tracts were fewer in number—such as in the wealthiest tracts (which feature more three-way, or *T*, intersections)—the number of injured cyclists would be reduced significantly. While poorer neighborhoods tend to have reduced road and sidewalk quality, the design of the neighborhood itself might either contribute to or protect against cycling injury.

Ultimately, lower SES seems to be the overarching factor in an individual's ability or inability to eliminate risk factors for pedalcyclist injury or fatality, including being able to afford safety-promoting items such as a helmet. Lang (2007) reported that in areas without helmet legislation, the odds of wearing a helmet was lowest among children living in households with unskilled workers and among those living in urban areas, as compared with rural or suburban children. Similarly, Embree et al. (2016) reported that children who were engaged in cycling on the road or in public places were more likely to be admitted to a hospital or trauma center for head injury than those who bicycled in a residential area. Factors such as living in urban areas and working unskilled jobs are often correlates of lower SES.

Though risk factors and neighborhood characteristics are likely different for individuals living in rural and urban areas, the findings from this study suggest that it is possible that low SES—measured in the current report by state poverty rates and educational levels—is an important predictor of pedalcyclist fatality irrespective of population size characteristics. Accordingly, state legislatures could consider numerous measures that improve cycling safety. Improving streets and sidewalks, altering neighborhood design by reducing the number of busy intersections, creating and promoting cycling infrastructure, and passing cycling safety-related legislation are approaches that might foster greater numbers of cyclists while reducing fatality rates. Cities with the highest proportion of cyclists tend to feature the safest cycling, whereas those with the lowest shares of cycling are typically most dangerous, though it is unknown whether the increase in cycling leads to greater population safety (i.e., via "safety in numbers"; Fyhri et al., 2017) or whether the establishment and enforcement of safety measures facilitates a greater number of cyclists (Pucher et al., 2011). Regardless, states should adopt policies that increase safety for their poorest citizens, many of whom might be more likely to use cycling as a purely utilitarian mode of transit.

Limitations

The findings in this study should be interpreted with a few limitations in mind. First, secondary data were used in this ecological study. Surveillance regarding pedalcyclist fatalities may be inaccurate and state-level understandings of SES may be incomplete, thereby making accurate assessments about the relationship between the variables difficult. Second, we examined trends across a limited 3-year period. Researchers should build from this study's findings to examine pedalcyclist fatality trends across wider time scales. Third, the unit of analysis in this study was states in the United States. Future spatial epidemiological studies may investigate the problem of pedalcyclist fatalities at a finer unit of resolution, viz., county, and introduce rurality as a variable—as such, a study design may eliminate some of the limitations encountered in this study and permit more targeted suggestions for public health practice.

Conclusion

To our knowledge, this is the first study to examine the predictive value of state poverty rates and educational levels on pedalcyclist fatalities with a spatiotemporal approach. Our findings suggest that the states with the least educated and poorest individuals also have the highest PFR. To improve cycling safety for those using bicycles recreationally and for commuting, states should not only adopt legislation and infrastructure that support cycling but should also consider urging community leaders to implement unique public safety programs, such as Lifeskills, in impoverished areas (Teyhan et al., 2016). An evaluation of the Lifeskills program—which provides students with the opportunity to experience risk in a simulated indoor village comprising roads, houses, rivers, and railways—showed that, compared to a control group, Lifeskills students more frequently reported wearing a cycle helmet (35.8% vs. 37.1%). As such, risk for fatalities from cycling, an outdoor form of recreation, may attenuate in areas where children have access to such programs.

References

American Psychological Association. (2016). Socioeconomic status. Retrieved from http://www.apa.org/topics/socioeconomic-status/

Cavill, N., & Davis, A. (2003). *Cycling and health*. Retrieved from http://www.cycle-helmets.com/cycling_and_health.pdf

Donatelle, R. J., & Ketcham, P. (2013). *Access to health*. Chicago, IL: Pearson.

Edwards, P., Green, J., Lachowycz, K., Grundy, C., & Roberts, I. (2008). Serious injuries in children: Variation by area deprivation and settlement type. *Archives of Disease in Childhood, 93,* 485–489. https://doi.org/10.1136/adc.2007.116541

Embree, T. E., Romanow, N. R., Djerboua, M. S., Morgunov, N. J., Bourdeaux, J. J., & Hagel, B. E. (2016). Risk factors for bicycling injuries in children and adolescents: A systematic review. *Pediatrics, 138*(5), 1–13. https://doi.org/10.1542/peds.2016-0282

Freedman, D. A. (1981). Bootstrapping regression models. *Annals of Statistics, 9*, 1218–1228. https://doi.org/10.1214/aos/1176345638

Fyhri, A., Sundfor, H. B., Bjornskau, T., & Laureshyn, A. (2017). Safety in numbers for cyclists: Conclusions from a multidisciplinary study of seasonal change in interplay and conflicts. *Accident Analysis and Prevention, 105*, 124–133. https://doi.org/10.1016/j.aap.2016.04.039

Gaudet, L., Romanow, N. T., Nettel-Aquirre, A., Voaklander, D., Hagel, B. E., & Rowe, B. H. (2015). The epidemiology of fatal cyclist crashes over a 14-year period in Alberta, Canada. *BMC Public Health*, *15*, 1–8. https://doi.org/10.1186/s12889-015-2476-9

González-Velasco, E. A. (2010). *Journey through mathematics: Creative episodes in its history*. New York, NY: Springer.

Kim, J., Kim, S., Ulfarsson G., & Porrello, L. (2007). Bicyclist injury severities in bicycle–motor vehicle accidents. *Accident: Analysis and Prevention, 39*, 238–251. https://doi.org/10.1016/j.aap.2006.07.002

Lang, I. A. (2007). Demographic, socioeconomic, and attitudinal associations with children's cycle-helmet use in the absence of legislation. *Injury Prevention, 13*, 355–358. https://doi.org/10.1136/ip.2007.015941

League of American Bicyclists. (2017). *Bicycle friendly America*. Retrieved from http://www.bikeleague.org/bfa

McClean, M. (2012). *Strategies for increasing bikeability: A closer look at the St. Louis regional bike plan* (Unpublished master's thesis). Washington University, St. Louis, MO.

Mitchell, R. J., & Bambach, M. R. (2015). Examination of narratives from emergency department presentations to identify road trauma, crash, and injury risk factors for different age groups. *Health Information Management Journal*, *44*(1), 21–29. https://doi.org/10.1177/183335831504400103

Mooney, C. Z., & Duval, R. D. (1993). *Bootstrapping: A nonparametric approach to statistical inference*. London, England: Sage. https://doi.org/10.4135/9781412983532

Morency, P., Gauvin, L., Plante, C., Fournier, M., & Morency, C. (2012). Neighborhood social inequalities in road traffic injuries: The influence of traffic volume and road design. *American Journal of Public Health, 102*, 1112–1119. ttps://doi.org/10.2105/AJPH.2011.300528

National Center for Statistics and Analysis. (2016). *Traffic Safety Facts: 2014 Data. Bicyclists and other cyclists* (DOT HS 812 282). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812282

National Highway Traffic Safety Association. (2013). *Traffic Safety Facts: 2011 Data*. *Bicyclists and other cyclists* (DOT HS 811 743). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811743

National Highway Traffic Safety Association. (2014). *Traffic Safety Facts: 2012 Data*. *Bicyclists and other cyclists* (DOT HS 812 018). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812018

National Highway Traffic Safety Association. (2015). *Traffic Safety Facts: 2013 Data*. *Bicyclists and other cyclists* (DOT HS 812 151). Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812151

Pampel, F. C., Krueger, P. M., & Denney, J. T. (2010). Socioeconomic disparities in health behaviors. *Annual Review of Sociology*, *36*, 349–370. https://doi.org/10.1146/annurev.soc.012809.102529

Pinhas, M., Tzelgov, J., & Ganor-Stern, D. (2012). Estimating linear effects in ANOVA designs: The easy way. *Behavioral Research, 44*, 788–794. https://doi.org/10.3758/s13428-011-0172-y

Pucher, J., Buehler, R., & Seinen, M. (2011). Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies. *Transportation Research Part A: Policy and Practice, 45*, 451–475. https://doi.org/10.1016/j.tra.2011.03.001

QGIS Development Team. (2009). *QGIS geographic information system: Open source geospatial foundation*. Retrieved from http://qgis.osgeo.org/

R Core Team. (2018). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing.

Rodgers, G. B. (1992). *Part I. An overview of the bicycle study*. Retrieved from https://www.cpsc.gov/s3fs-public/pdfs/344.pdf

Schepers, P., Hagenzieker, M., Methorst, R., van Wee, B., & Wedman, F. (2014). A conceptual framework for road safety and mobility applied to cycling safety. *Accident Analysis and Prevention, 62*, 331–340. https://doi.org/10.1016/j.aap.2013.03.032

Shields, M. M., Thomas, K. H., Paschal, A., Tucker, M., Leeper, J., & Usdan, S. (2017). Promoting campus cycling for outdoor recreation and transportation: Investigating factors influencing student bicycle usage on a large, southeastern university from an ecological perspective. *Journal of Outdoor Recreation, Education, and Leadership, 9*, 98–112. https://doi.org/10.18666/JOREL-2017-V9-I1-7475

Teyhan, A., Cornish, R., Macleod, J., Boyd, A., Doerner, R., & Joshi, M. S. (2016). An evaluation of the impact of 'Lifeskills' training on road safety, substance use, and hospital attendance in adolescence. *Accident Analysis and Prevention, 86*, 108–113. https://doi.org/10.1016/j.aap.2015.10.017

Thompson, M. J., & Rivara, F. P. (2001). Bicycle-related injuries. *American Family Physician*, *63*, 2007–2013.

Traynor, T. L. (2009). The impact of state level behavioral regulations on traffic fatality rates. *Journal of Safety Research, 40*, 421–426. https://doi.org/10.1016/j.jsr.2009.10.003

U.S. Census Bureau. (2018). Historical poverty tables: People and families, 1959–2015. Retrieved from https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-people.html

U.S. Department of Transportation, Federal Highway Administration. (2002). Who's walking and bicycling. Retrieved from http://www.pedbikeinfo.org/data/factsheet_general.cfm

Vargo, J., Gerhardstein, B. G., Whitfield, G. P., & Wendel, A. (2015). Bicyclist deaths associated with motor vehicle traffic—United States, 1975–2012. *Morbidity and Mortality Weekly Report*, *64*, 837–841. https://doi.org/10.15585/mmwr.mm6431a1

Yu, C. (2014). Environmental supports for walking/biking and traffic safety: Income and ethnicity disparities. *Preventive Medicine, 67*, 12–16. https://doi.org/10.1016/j.ypmed.2014.06.028