Urban Sprawl and Miles Driven Daily by Teenagers in the United States

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Background: Urban sprawl's association with increased automobile reliance and daily mileage is well established among adults. However, sprawl's specific impact on teen driving exposure is unknown. Teen driver fatality rates per mile driven are significantly higher than adults, making the identification of environmental influences on travel behavior particularly important in this age group.

Methods: Driving and demographic data for 4528 teens (weighted=10.5 million) aged 16–19 years were obtained from the 2001 National Household Transportation Survey (NHTS). County-level sprawl was measured using an index developed by Ewing et al. The association between daily miles driven by teens and sprawl, controlling for demographic characteristics, was modeled using ordinal logistic regression. The predicted probability of driving >20 miles in counties with varying degrees of sprawl also was calculated.

Results: Of the surveyed teens, 48% did not drive, 27% drove <20 miles/day, and 25% drove >20 miles/day. Of the 52% of teens who reported driving, the average distance driven was 15.6 miles/day. More-pronounced sprawl was associated with increased daily mileage ($p<0.001$). Overall, teens in sprawling counties were more than twice as likely to drive >20 miles/day than teens in compact counties. This trend was most prominent among the youngest drivers. For example, the predicted probability of boys aged 16–17 years driving >20 miles per day varied from 9% to 24% in compact versus sprawling counties.

Conclusions: Sprawl is associated with increased daily mileage by teen drivers. Given the stark relationship between driving exposure and fatality risk among teens, increased efforts to understand and modify the effects of sprawl on adolescent driving behavior are necessary.
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Background

Despite dramatic improvements in automotive safety engineering over the past few decades, motor vehicle crashes remain the most common cause of death among adolescents in the United States.[1] More than 3500 drivers aged 15–20 years died and more than 300,000 were injured in motor vehicle crashes in 2004.[2]

Driving is a particularly dangerous activity for teens. Per mile driven, teens are involved in four to eight times the number of fatal crashes than mature drivers,[3] due in large part to a confluence of developmental factors including normative risk taking and individual personality traits.[4] As a result, dangerous driving behaviors such as speeding, close following, or seat belt non-use, which are prevalent among adolescents, are not readily amenable to change.[4]

Given the recalcitrant nature of adolescent risk behaviors, many teen driver safety interventions, such as graduated drivers licensing,[5] instead attempt to limit driving exposure during this high-risk period of early skill building. Minimizing driving exposure among the youngest and most novice teens (those aged 16–17 years) appears to be particularly important given their greatly increased risk of crash involvement.[6,7]

In support of these efforts to reduce miles driven by teens, it is necessary to identify environmental factors, such as urban sprawl, that potentially influence adolescent travel behavior. Sprawl is a development pattern typified by low-density construction, poor street connectivity, and minimal land-use mix[8] that has been previously associated with increased automobile dependency and driving exposure among adult drivers.[8,9] Sprawl's relationship to driving exposure has not been specifically evaluated among adolescents. However, similar to adults, the total daily miles driven by teens are likely increased in sprawling counties compared with teens living in more-compact counties. Confirmation of this hypothesis could have considerable policy and

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research implications given the demonstrated importance of limiting driving exposure in this age group to reduce fatality risk from motor vehicle crashes.

Methods

To determine the relationship between urban sprawl and teen driving exposure in the U.S., a cross-sectional analysis was conducted of national travel behavior data for adolescents linked to county-level measures of sprawl.

National Household Transportation Survey

National driving exposure and demographic data for teens aged 16–19 years were obtained from the 2001 National Household Transportation Survey (NHTS).[10] The NHTS is a national random-digit-dial telephone survey conducted periodically by the Department of Transportation to provide a comprehensive measure of transportation patterns in the U.S. The most recent NHTS, performed in 2001, collected data on 66,000 households between March 2001 and May 2002 and had a weighted person-level composite/overall response rate of 34.1%. Data collection consists of three phases. An initial interview documents all individuals and available vehicles in the household. The household is also assigned a 24-hour "travel day" and mailed a diary to record and describe all trips taken during this time period. Individual interviews are conducted with each person in the household to document specifics of his/her travel. The NHTS data sets include probability weights that incorporate several stages of nonresponse and noncoverage adjustment based on 2000 national census data to reduce sampling error and bias. Replicate weights are also included to allow calculation of standard errors that account for the survey's complex design. A full description of the NHTS sampling scheme and weighting procedure is available online at http://nhts.ornl.gov.

See related Commentary by Matthews in this issue.

County Sprawl Index

County-level sprawl was measured using index scores previously developed by Ewing et al.[11] This validated index is a composite of factors incorporating measures of residential density, segregation of land use, strength of metropolitan centers, and accessibility of the street network.[9,12] Higher index values indicate counties with more-compact development (i.e., less sprawl). At the time of analysis, sprawl indices were available for 954 counties or county equivalents in the U.S. The sprawl index is available for most Census-defined metropolitan counties; some exceptions are the District of Columbia and independent cities in Virginia. The mean sprawl index score of these counties was 94.2 (SD=19). The median value was 92.7 (Delta County; Dallas–Fort Worth–Arlington TX). The values were highly skewed and ranged from 55 (Jackson County; Topeka KS) to 352 (Manhattan–New York County NY).

Analysis

As a measure of teen driving exposure (dependent variable), the total mileage driven by each surveyed teen during their 24-hour travel period was calculated. Only trips in which the teen was the driver of a vehicle were included (i.e., mileage as a passenger excluded). Teens reporting no miles driven during their travel day were included in the final analysis. All trip mileages were self-reported; validation studies have shown that trips of less than 10 minutes tend to be underreported.[13]

Preliminary analysis indicated that the total daily mileage reported in the sample was highly skewed and contained a large proportion of teens reporting no miles driven. For this reason, total daily mileage was analyzed as a three-level categoric variable (no driving, ≤20 miles, >20 miles) using ordinal logistic regression. These two mileage cut-points roughly corresponded to the 50th and 75th percentiles of the outcome measure (total daily miles driven). A small percentage of teens (<1%) reported very high daily mileage (>130 miles) that was generally attributable to vacations or work-related travel. Excluding these observations did not affect the overall results. Therefore, these cases were retained in order to describe most accurately the travel patterns recorded by the NHTS sample.

The primary independent variable of interest was county-level sprawl as measured by the index score described previously. Previous studies have utilized this measure in analyses as a continuous variable.[9,12,14] This is preferred since it maximally preserves the information available from the data. However, use of a continuous predictor assumes a linear association between it and the dependent variable. The linearity of the sprawl index with the three-category outcome was investigated by creating an ordinal categoric variable based on the deciles of the sprawl index. The gamma statistic and a Mantel–Haenszel test of linear association indicated a significant linear trend with the percentage of nondrivers tending to increase and the percentage of teens driving >20 miles a day tending to decrease with increasing sprawl index categories (i.e., more-compact development). In addition, tests of higher-order (quadratic) relationships showed no evidence of such an effect. Therefore the county sprawl index was utilized in the analyses as a continuous variable.

Dummy variables for household income ($5,000–$24,999; $25,000–$49,999; $50,000–$74,999; ≥$75,000; undetermined); gender; race; ethnicity; age (16–17 years, 18–19 years); and single-parent households also were included in the final model to control for potentially important individual and household characteristics

Person weights and replicate weights provided in the 2001 NHTS data sets were utilized in all analyses to account for the complex design of the travel survey and ensure accurate calculation of standard errors. Final multivariate regression was performed using the *svy: ologit* and *prvalue* commands in STATA, version 9.2. Predicted probabilities of sampled teens driving >20 miles in a day were calculated for age and gender subgroups at three levels of sprawl (compact, average, and sprawling). These sprawl values corresponded approximately to the mean sprawl index value for all measured counties (n=954) in the U.S. ± two standard deviations.

Results

Demographics

The NHTS sample included 6859 eligible teens representing a weighted population of approximately 14.3 million youth. Sprawl values were available for 4572 (67%) teens

Table 1. Variable definitions and sample statistics for youth aged 16–19 years from the 2001 National Household Transportation Survey (NHTS)

Variables	Unweighted (%)	Weighted (%)
Age (years)		
16–17	60.3	51.0
18–19	39.7	49.0
Gender		
Female	47.9	48.8
Male	52.1	51.2
Race/ethnicity		
White (non-Hispanic)	82.5	65.3
African-American (non-Hispanic)	5.6	14.8
Hispanic	7.3	15.1
Asian/Pacific Islander	2.3	2.8
Multi-ethnicity	2.3	2.0
Household income ($)		
5000–24,999	13.1	18.7
25,000–49,999	25.4	26.1
50,000–74,999	22.4	19.0
≥75,000	32.7	28.9
Undetermined	6.4	7.3
Single-parent household	13.9	14.8
Household vehicles		
No vehicles	3.6	5.5
At least one vehicle	96.4	94.5
County sprawl[a]		
Sprawl Index for county of residence	107.2 (mean)	114.3 (mean)
Teen driving exposure (daily miles as driver)		
No driving	47.8	54.1
<20 miles	27.2	22.0
≥20 miles	25.0	23.9

[a]Higher values of the county sprawl index correspond to more-compact development, lower values to more sprawling development.

in the sample. In 89% of the cases where sprawl values were unavailable, it was because the teens lived in a rural area where the sprawl index did not apply. Forty-four individuals were excluded due to missing driving data. Therefore, the final sample included 4528 teens aged 16–19 years representing a weighted subpopulation of approximately 10.5 million adolescents. Fifty-two percent of the unweighted sample were girls, and 60% was either 16 or 17 years old (Table 1). Ninety-six percent of teens reported at least one household vehicle.

Sample Sprawl Indices

The mean sprawl index value of the unweighted sample was 107.2 (SD=33.6) and ranged from 62.5 (Bedford County; Lynchburg VA) to 352.1 (New York County NY). The median county index value was 101.0 (Cobb County; Atlanta–Sandy Springs–Marietta GA).

Daily Mileage Driven

Forty-eight percent of surveyed teens did not drive, 27% drove <20 miles, and 25% drove >20 miles. Of the 52% of teens who reported driving, the average distance driven was 15.6 miles per day (median=2 miles). Total daily mileage ranged from 0 to 583 miles with 95% of teens driving 66 miles or less.

Urban Sprawl and Daily Miles Driven

The association between sprawl and total daily mileage by teen drivers was measured while controlling for important individual, household, and place characteristics using ordinal logistic regression (Table 2). More-pronounced sprawl (i.e., lower index values) was significantly associated with higher total daily miles driven by teens ($p<0.001$) while holding other predictors in the model fixed.

To further quantify this relationship, the predicted probability of teens driving >20 miles was calculated for three sprawl index values while controlling for other important predictors (Table 3). These index values were chosen to approximate counties with average, compact, and sprawling development. Overall, teens in sprawling counties were more than twice as likely to drive >20 miles a day than teens living in compact counties. This trend was especially pronounced in younger drivers (16–17 years). For example, after controlling for important covariates, the predicted probability of boys aged 16–17 years driving >20 miles per day varied from 9% in compact counties to 24% in sprawling counties. Similarly, the predicted probability of girls aged 16–17 years driving >20 miles

Table 2. Ordinal logistic regression of association between daily miles driven by teens aged 16 to 19 years and county sprawl index, controlling for demographic and socioeconomic characteristics

	Daily mileage driven, no driving, <20 miles, ≥20 miles	
	Odds ratio (95% CI)	***p***
County sprawl index[a]	0.985 (0.981–0.989)	<0.001
Age (years)		
16–17	0.355 (0.293–0.431)	<0.001
18–19	Ref	
Female	0.708 (0.578–0.867)	0.001
Race/ethnicity		
African-American	0.292 (0.181–0.473)	<0.001
Hispanic	0.489 (0.341–0.701)	<0.001
Asian and Pacific Islander	0.775 (0.367–1.634)	0.499
Multi-ethnic	0.670 (0.309–1.454)	0.308
White	Ref	
Single-parent household	1.12 (0.826–1.510)	0.471
Household income ($)		
5000–24,999	Ref	
25,000–49,999	1.637 (1.138–2.356)	0.008
50,000–74,999	2.146 (1.546–2.979)	<0.001
≥75,000	2.585 (1.794–3.723)	<0.001
Undetermined	1.35 (0.818–2.232)	0.237

[a]Higher values of the county sprawl index correspond to more-compact development, lower values to more sprawling development. CI, confidence intervals; Ref, reference category.

Table 3. Predicted probability of adolescents driving >20 miles per day by county-level sprawl, age, and gender[a]

		County-level sprawl (95% CI)		
Age (years)	**Gender**	**Compact (I=132)[b]**	**Average (I=94)[b]**	**Sprawling (I=56)[b]**
All teens	Both	21.7 (14.7–28.6)	33.0 (25.5–40.6)	46.8 (38.4–55.2)
16–17	Male	9.0 (5.8–12.1)	14.9 (10.8–19.1)	23.8 (17.8–29.9)
	Female	6.5 (4.2–8.9)	11.0 (7.7–14.4)	18.1 (12.7–23.6)
18–19	Male	22.9 (12.3–33.4)	38.5 (24.4–52.6)	56.9 (42.3–71.6)
	Female	16.4 (11.0–21.8)	25.9 (19.3–32.5)	38.4 (29.8–47.0)

[a]All probabilities calculated using reference household income level ($25,000–$50,000).
[b]Sprawl categories represent the mean index value (94.2) ± two standard deviations (SD=19). Higher values of the county sprawl index correspond to more-compact development, lower values to more sprawling development.
I = county-level sprawl index value.

per day varied from 7% in compact counties to 18% in sprawling counties.

Discussion

The results of this study support the hypothesis that sprawl is significantly associated with increased daily driving mileage by teen drivers. Adolescents living in counties with sprawling development are more than twice as likely to drive >20 miles each day than those in more-compact counties. These findings are important given the enormity of teen driver safety as a public health issue and the particularly stark relationship between driving exposure and risk of severe injury or death among novice teen drivers.[2,3] These results also suggest that the proliferation of sprawling development in the U.S. may undermine the shared goal of decreasing driving exposure among adolescents during their high-risk period of early skill acquisition.

Why might this be the case? Studies of adults have shown that people drive more in areas typified by low-density housing organized in "loops and lollipops" along central feeder roads with poor street connectivity.[8,11] Vehicle miles traveled are higher in areas with more-pronounced sprawl because trip distances are longer and alternative modes, such as walk, bike, or transit, may be impractical.[15,16] These same forces likely cause teens in sprawling areas to substitute driving for walking or taking public transit. In addition, living in areas with good public transit service and proximate destinations actually may decrease demand for becoming licensed drivers. The relationship between teen licensure and the built environment remains unexamined and is a promising area for further research.

Finally, the location of schools may affect how much teens drive. Several authors have noted that the school siting guidelines existing prior to 2004 encouraged districts to build schools on large parcels.[17–19] In many communities such parcels are available only on the edge of town, often removed from the residential developments they serve. This geographic arrangement increases distance to school and it is well-established that distance is the most critical factor in whether youth walk to school.[20] Recent efforts to encourage the coordination of school and land-use planning may lead to more walkable schools. However, the size of high schools—often more then 1000 students—reduces opportunities to locate the schools close to most students, except in very dense areas.

Limitations

There are several limitations to this study. The use of cross-sectional data only allows for the determination of sprawl's association with increased daily driving exposure, rather than causation due to issues such as potential self-selection bias. Alternatively, the use of youth-related data may minimize this issue given the fact that children do not make household location decisions.[21] In addition, the county-level sprawl measure used in this analysis is fairly coarse and therefore cannot distinguish the significant variation in development patterns that exist within most counties. The effect of using such an aggregate spatial scale will likely be to bias the coefficients lower, that is, to underestimate the effect of sprawl on driving. Future analyses would benefit from measures of sprawl at the neighborhood level.

Measuring distance alone also does not adequately describe differences in driving contexts (e.g., traffic density, typical road designs, average speed) between compact and sprawling communities. The densest areas may have highly congested roads that reduce average vehicle speeds; residents of newer communities located at the urban edge often face less-congested conditions and therefore drive at higher average speeds. Increased speed is associated with higher crash incidence and injury or fatality risk.[8]

Finally, it was not possible to control for variation in licensing restrictions that existed among states at the time of the 2001 NHTS. Data specifying the implementation date and enforcement guidelines of licensing restrictions by state are not available. However, despite lack of adjustment for these regulatory factors, it is unlikely that the overall findings would be altered

because most states display significant variation in the sprawl index across counties.

Conclusion

Teens living in counties characterized by pronounced sprawl drive significantly more miles each day than similar teens in more-compact counties. Higher travel exposure increases "time at risk" and therefore the risk of severe injury or death. This is particularly true for teen drivers since their fatality rates are four to eight times higher per mile traveled than that of mature drivers. Further research is needed to delineate more specifically the impact of development patterns, such as sprawl, on teen driving behavior and subsequent injury risk. However, it is clear that the long-term success of initiatives to minimize driving exposure by novice teens may be hampered if efforts to limit sprawling development are not also vigorously pursued.

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References

1. National Highway Traffic Safety Administration. Traffic safety facts (2004 data): Young drivers. Available online at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/ncsa/TSF2004/809918.pdf.
2. Insurance Institute of Highway Safety. Fatality facts 2004: Teenagers. Available online at: http://www.hwysafety.org/research/fatality_facts/pdfs/teenagers.pdf.
3. Gonzales MM, Dickinson LM, DiGuiseppi C, Lowenstein SR. Student drivers: a study of fatal motor vehicle crashes involving 16-year-old drivers. Ann Emerg Med 2005;45:140–6.
4. Shope JT. Influences on youthful driving behavior and their potential for guiding interventions to reduce crashes. Inj Prev 2006;12(Suppl 1):i9–14.
5. Insurance Institute for Highway Safety. Graduated licensing: A blueprint for North America, 2004. Available online at: http://www.iihs.org/research/topics/teenagers.html.
6. McCartt AT, Shabanova VI, Leaf WA. Driving experience, crashes and traffic citations of teenage beginning drivers. Accid Anal Prev 2003;35:311–20.
7. Williams AF. Teenage drivers: Patterns of risk. J Safety Res 2003;34:5–15.
8. Frumkin H, Frank L, Jackson R. Urban sprawl and public health: designing, planning, and building for healthy communities. Washington DC: Island Press, 2004.
9. Ewing R, Schieber RA, Zegeer CV. Urban sprawl as a risk factor in motor vehicle occupant and pedestrian fatalities. Am J Public Health 2003;93:1541–5.
10. Federal Highway Administration. 2001 National Household Transportation Survey. Washington DC: U.S. Department of Transportation, 2001.
11. Ewing R, Pendall R, Chen D. Measuring sprawl and its transportation impacts. Transportation Research Record 2003;1831:175–83.
12. Ewing R, Brownson RC, Berrigan D. Relationship between urban sprawl and weight of United States youth. Am J Prev Med 2006;31:464–74.
13. Zmud J, Wolf J. Identifying the correlates of trip misreporting: Results from the California Statewide Household Travel Survey GPS Study. In: 10th International Conference on Travel Behaviour Research; 2003 August 10–15, 2003; Lucerne, Switzerland; 2003. Available online at: http://www.ivt.baug.ethz.ch/allgemein/pdf/zmud.pdf.
14. Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Relationship between urban sprawl and physical activity, obesity, and morbidity. Am J Health Promot 2003;18:47–57.
15. Lee C, Moudon AV. The 3Ds + R: Quantifying land use and urban form correlates of walking. Transportation Research Part D: Transport and Environment 2006;11:204–15.
16. Ewing R, Cervero R. Travel and the built environment: a synthesis. Transportation Research Record 2001;1780:87–114.
17. Beaumont C, Pianca EG. Historic neighborhood schools in the age of sprawl: Why Johnny can't walk to school. Washington DC: National Trust for Historic Preservation, 2002.
18. Council of Educational Facility Planners International. Guide for planning educational facilities. Scottsdale AZ: Council of Educational Facility Planners International, 1991.
19. Council of Educational Facility Planners International. Creating connections: the CEFPI guide to educational facility planning. Scottsdale AZ: Council of Educational Facility Planners International, 2004.
20. McDonald N. Active transportation to school: trends among U.S. schoolchildren, 1969–2001. Am J Prev Med 2007;32:509–16.
21. Raphael S. The spatial mismatch hypothesis of black youth joblessness: evidence from the San Francisco Bay Area. J Urban Econ 1998;43:79–111.