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RESEARCH ARTICLE

Trends in Automobile Travel, Motor Vehicle Fatalities, and Physical Activity: 2003−2015

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Introduction: Annual per-capita automobile travel declined by 600 miles from 2003 to 2014 with decreases greatest among young adults. This article tests whether the decline has been accompanied by public health co-benefits of increased physical activity and decreased motor vehicle fatalities.

Methods: Minutes of auto travel and physical activity derived from active travel, sports, and exercise were obtained from the American Time Use Survey. Fatalities were measured using the Fatality Analysis Reporting System. Longitudinal change was assessed for adults aged 20–59 years by age group and sex. Significance of changes was assessed by absolute differences and unadjusted and adjusted linear trends. Analyses were conducted in 2016.

Results: Daily auto travel decreased by 9.2 minutes from 2003 to 2014 for all ages ($p<0.001$) with the largest decrease among men aged 20–29 years ($\Delta= -21.7$, $p<0.001$). No significant changes were observed in total minutes of physical activity. Motor vehicle occupant fatalities per 100,000 population showed significant declines for all ages ($\Delta=-5.8$, $p<0.001$) with the largest for young men ($\Delta= -15.3$, $p<0.001$). Fatalities per million minutes of auto travel showed only modest declines across age groups and, for men aged 20–29 years, varied from 10.9 (95% CI=10.0, 11.7) in 2003 to 9.7 (95% CI=8.7, 10.8) in 2014.

Conclusions: Reduced motor vehicle fatalities are a public health co-benefit of decreased driving, especially for male millennials. Despite suggestions to the contrary, individuals did not switch from cars to active modes nor spend more time in sports and exercise. Maintenance of the safety benefits requires additional attention to road safety efforts, particularly as auto travel increases.
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INTRODUCTION

A strange thing occurred in the 2000s. Automobile usage, which had risen steadily since the invention of the internal combustion engine, began to decline. Federal statistics show that per-capita driving declined by nearly 600 miles annually between 2004 and 2014.[1] Decreases in driving were not uniform; members of the millennial generation, born in the 1980s and early 1990s, experienced the largest declines.[2,3] Analysts have linked the decrease in driving to economic factors associated with the global financial crisis and gas prices.[3,4] However, other shifts are important, including changing lifestyles among young adults, increased debt levels, and changing attitudes toward travel.[5–7] Whatever the cause, there is agreement that Americans, particularly young adults, experienced a large decrease in automobile travel. Previous work speculated that widespread decreases in driving could have public health co-benefits by increasing physical activity and reducing injuries and fatalities from motor vehicle crashes.[8–10]

Aggregate driving on American roads peaked in 2007, declined through 2011, and has only recently (2015) returned to pre-recession levels.[1] On a per-capita basis, declining automobility was evident prior to the global financial crisis and continued through 2014.[1,11,12] Since 2014, per-capita driving has increased but has not yet

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returned to pre-recession peaks. Investigations of these trends have found that young adults, particularly men, experienced the largest decreases.[13] But decreases were also large in lower-density areas and among the unemployed.[6] Teens and young adults have also been less likely to become licensed drivers in recent decades—a phenomenon noted across industrialized countries.[14,15]

Automobile travel is influenced by many factors from macroeconomic trends in gross domestic product, employment, and gas prices to individual preferences on residential location, travel mode, and activity location. The advent of the internet has led to new ways of traveling, such as the ridesharing app Uber, and improved the experience of using traditional modes through innovations in real-time journey planning. Disentangling the influences of these factors is difficult. Researchers agree that economic factors related to the global financial crisis; long-term trends in young adult employment, income, and debt patterns; and the changing costs of driving due to gas price volatility contributed to decreased driving.[3,4,6] However, declines are also affected by lifestyle shifts, particularly among younger Americans, which have led to delayed attainment of life milestones, such as household formation, partnering, and parenthood.[5,6] Some researchers also contend that additional factors, such as changing residential and travel preferences, are involved in the decline in driving.[7]

Although there has been little attention paid to the public health impacts of recently observed decreases in driving, a series of articles assessed the potential for peak oil, generally defined as the point in time when oil extraction reaches a maximum and thereafter declines, to impact public health.[9,10] Schwartz et al.[10] outline the multilevel impacts of petroleum scarcity on public health, highlighting the need to reduce petroleum dependence in order to increase resilience to volatility in petrol supply and prices. Concern about peak oil has waned as new extraction technologies have increased the accessible supply of oil.[16] Nevertheless, these articles provide a framework for identifying how a shift away from automobiles could impact public health. Frumkin and colleagues[9] predict that a decrease in driving "could yield substantial health benefits, including more physical activity, reduced air pollution, and reduced traffic-related injuries and fatalities." This article focuses on motor vehicle crashes and physical activity because of the availability of national data allowing quantification of impacts. Physical activity could increase as a result of a shift from motor vehicles to active modes of travel. Reduced time spent in cars may also allow more time for other activities associated with physical activity, such as leisure active travel and participation in sports and exercise.

Motor vehicle crashes are a leading cause of death in the U.S., with more than 30,000 dying on the roads in 2014, at an estimated cost of $277 billion in 2010.[17] Research has shown that crashes are influenced by individual factors related to risk taking, vehicle safety technology, government regulations around licensure, and macroeconomic conditions.[18] Previous analyses show decreases in fatalities during economic recessions due to decreased driving.[19,20] Attention has also been paid to crash patterns for teen drivers.[21] The introduction of Graduated Driver License schemes in recent decades has been linked to decreased injuries and fatalities for the youngest drivers.[22,23]

The goal of the study is to assess two types of public health co-benefits of recent decreases in driving: changes in physical activity and motor vehicle fatalities. The study also documents trends in automobile travel. Two data sources are used in the analysis: the American Time Use Survey (ATUS) and the Fatality Analysis Reporting System. The analysis reports trends for working-aged adults (20–59 years) and highlights variation by age group because previous research has shown large differences by age.

METHODS

Data Sample

Conducted annually since 2003, ATUS records activity and activity durations in American households.[24] The survey is a repeated cross-section with respondents drawn from the sample for the U.S. Census Bureau's Current Population Survey. ATUS provides a consistent way to compare time in cars to time engaging in physical activity and has longer and more complete longitudinal coverage than national travel surveys; however, trip distances are not available from the time use data.

Four time use metrics are extracted from the data. The first measures time spent traveling in a car, truck, or motorcycle as a driver or passenger. Physical activity related to active travel and sports participation is measured through time spent traveling by foot or bicycle, that is, utilitarian active travel; walking or bicycling for sport, that is, leisure active travel; and time playing sports and exercising, excluding walking and bicycling. These last three measures sum to provide a metric of physical activity derived from active travel and sports participation. This study does not consider physical activity related to other activities, such as playing with children or cleaning the house (Tudor-Locke et al.[25,26] provide approaches that characterize the activity intensity of the full ATUS activity categories).

The ATUS data reports on time use for 109,352 individuals aged 20–59 years between 2003 and 2014. Observations are dropped if there is missing information for location in region (n=686) and housing tenure (n=111). The final sample size is 108,556, which includes 18,277 individuals between 20 and 29 years. Sample sizes are 7,500–9,000 per year, with the exception of 2003, which had an eligible sample exceeding 14,000 records. This difference is due to budget cuts that reduced the sample from 2004 onward.[27] Table 1 provides the unweighted sample demographics and shows that the

Table 1. Unweighted Sample Demographics, ATUS, and Fatality Analysis Reporting System, 2003–2014

Variable	ATUS	Fatality Analysis Reporting System
n	108,556	293,292
Age, years, M (SE)	40.8 (0.03)	37.2 (0.02)
Age group		
20–29 years	0.17	0.34
30–39 years	0.29	0.22
40–59 years	0.54	0.44
Sex		
Male	0.44	0.74
Female	0.56	0.26
Race/ethnicity		
Non-Hispanic white	0.67	0.60
Non-Hispanic black	0.13	0.12
Hispanic	0.14	0.13
Other	0.06	0.04
Missing		0.11
Employment		
Employed	0.76	
Other	0.20	
Full-time student	0.04	
Location in region		
Metro, central city	0.26	
Metro, balance of area	0.43	
Metro, not identified	0.15	
Not in metropolitan area	0.17	
Child in household	0.57	
Household tenure		
Owned	0.70	
Rented for cash	0.29	
Occupied without payment	0.01	

Note: Values are proportions, unless otherwise noted.
ATUS, American Time Use Survey.

ATUS sample has strong representation across demographic subcategories.

Maintained by the National Highway Traffic Safety Administration, the Fatality Analysis Reporting System is a census of crashes that involve a fatality.[28] To be included in the database, deaths of motorists or non-motorists must have occurred within 30 days of the crash and the incident location has to be on a roadway open to the public. The data set provides information on the age, sex, race, and Hispanic origin of all fatalities.

The data set contains records for 449,332 fatalities from 2003 to 2014 across all ages during the study period. Demographic information is determined from crash records and death certificates. Records with missing age (*n*=976) or sex (*n*=121) were dropped from the analysis. The final census of fatalities for individuals aged 20–59 years was 293,292. Annual counts range from approximately 27,000 in 2003 to approximately 21,000 in 2014. Men make up 76% of recorded fatalities (Table 1). Racial and ethnic identity contains a large proportion of missing data (approximately 10%). The majority (86%) of reported fatalities involved motor vehicle occupants.

Statistical Analysis

The goal of this analysis was to measure changes in physical activity and motor vehicle−related fatalities during the recent period of sustained declines in driving and compare patterns by age. Changes in physical activity and fatalities were measured from 2003 to 2014 because the ATUS data on auto travel showed 2003 to have the highest per-person auto travel and 2014 to have the lowest for both adults aged 20–29 years and the full sample. Graphical data representations also included data for 2015 to provide up-to-date trends. Detailed methods for assessing changes in time use and fatality data are described here. All analyses were conducted in 2016 using Stata, version 14.

Descriptive statistics compared time spent in automobile travel and physical activity derived from active travel, sports, and exercise from 2003 to 2014. Metrics of change over time included absolute change in time use from 2003 to 2014, unadjusted linear trend, and adjusted linear trend. Unadjusted linear trends regress time use against a continuous survey year variable using individual-level data; this approach yields an estimate of average annual change in time use. Tables report unadjusted linear trends over the study period by multiplying average annual change (i.e., the coefficient on the survey year variable) by the number of years in the study period. Adjusted linear trends regress time use against survey year and demographic characteristics, thereby controlling for changes in sample composition that might independently affect time use (i.e., active travel is higher among faster-growing segments of the population). Demographic variables included in models were sex, race and ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other), location in region (central city, balance of metropolitan area, metropolitan area—not identified, not in metropolitan area), employment (employed, full-time student, other), housing tenure (owned, rented for cash, occupied without payment), and the presence of children in the household. Differences were analyzed by age group (20–29, 30–39, and 40–59 years) and by demographic subgroups defined by sex, race and ethnicity, employment, and location in region. Reported statistics and models used replicate weights provided by ATUS to adjust estimates for the complex sampling design and estimate SEs. Changes for younger Americans (aged 20–29 years) were compared to those for older adults (aged 40–59 years) to test whether young adults experienced disproportionate changes.

The population-adjusted death rate, defined as the number of fatalities divided by total population, was used to assess safety impacts of the decline in driving. Analyses distinguished the death rate for motor vehicle occupants and non-occupants, such as pedestrian and bicyclists. The number of fatalities was obtained from the Fatality Analysis Reporting System data; population estimates were from the U.S. Census Bureau's Population Estimates program and are available by state, year, age group, and sex.[29,30] To disaggregate the effects of changing exposure from other factors, exposure-adjusted death rates were computed. The metric of exposure was annual minutes of automobile travel, derived from ATUS. Analyses assessed changes in the population- and exposure-adjusted death rate by age group and sex; exposure-adjusted analyses did not consider non-occupant fatalities because of the difficulties of calculating exposure metrics. Racial and ethnic differences were not analyzed because of the large proportion of missing data for race and ethnicity for motor vehicle fatalities.

Change over time in population-adjusted death rates was assessed through absolute difference and model-estimated linear trends. Absolute difference was calculated as the simple difference between 2003 and 2014. Linear trends were estimated using state-level fixed-effects panel models that regressed population-adjusted death rates against a continuous survey year variable allowing the time effect to vary by sex and age. The regression models provide better inference because they utilize data from the full study period rather than only end points. For population-adjusted outcomes, models use data summarized by state (50 states and DC), age group (20–29, 30–39, and 40–59 years), and sex (male, female). To account for the differing population across segments, models were weighted by the average population for each group (e.g., women aged 20–29 years in Minnesota). Models were not used for exposure-adjusted death rates because samples were too small to calculate state-level exposures by age and sex. Instead, CIs were computed using the approach developed by Beck and colleagues.[31]

RESULTS

Minutes of automobile travel declined for working-aged adults between 2003 and 2014; all age groups showed upticks in auto travel between 2014 and 2015 (Figure 1). Absolute differences and linear models showed significant decreases for all age groups between 2003 and 2014 (Table 2). Young adults had significantly larger adjusted decreases compared with adults aged 40–59 years (p=0.022). Absolute decreases for young men (Δ= −21.7, $p<0.001$) were approximately twice those of young women (Δ= −9.7, $p<0.001$).

Total time spent in active travel and sports participation did not increase significantly from 2003 to 2014 as measured by absolute difference as well as unadjusted and adjusted linear trends (Figure 1, Table 2). Adjusted change in utilitarian active travel exhibited significant declines for adults aged 30–39 and 40–59 years; increases in leisure active travel for adults aged 20–29 years were significant; and no significant changes were observed for sports and exercise.

Analysis of young adults, aged 20–29 years, by demographic subgroups (defined by sex, race and ethnicity, employment, and location) revealed little variation from overall physical activity time use patterns shown in Table 2. No differences were observed for total physical activity. Adjusted decreases in utilitarian walking and bicycling were significant for women (Δ= −1.2, p=0.045) and Hispanics (Δ= −2.6, p=0.008). Women (Δ=1.4, p=0.018) and non-Hispanic whites (Δ=1.3, p=0.027) had significant increases from 2003 to 2014 in leisure active travel.

Annual fatalities declined by 1,941 (21%) for adults aged 20–29 years, 1,590 (25%) for those aged 30–39 years, and 2,157 (19%) for those aged 40–59 years between 2003 and 2014. Population-adjusted death rates for motor vehicle occupants showed large drops through 2014 with a recent uptick (Figure 1). For non-motor vehicle occupants, such as pedestrians or bicyclists, death

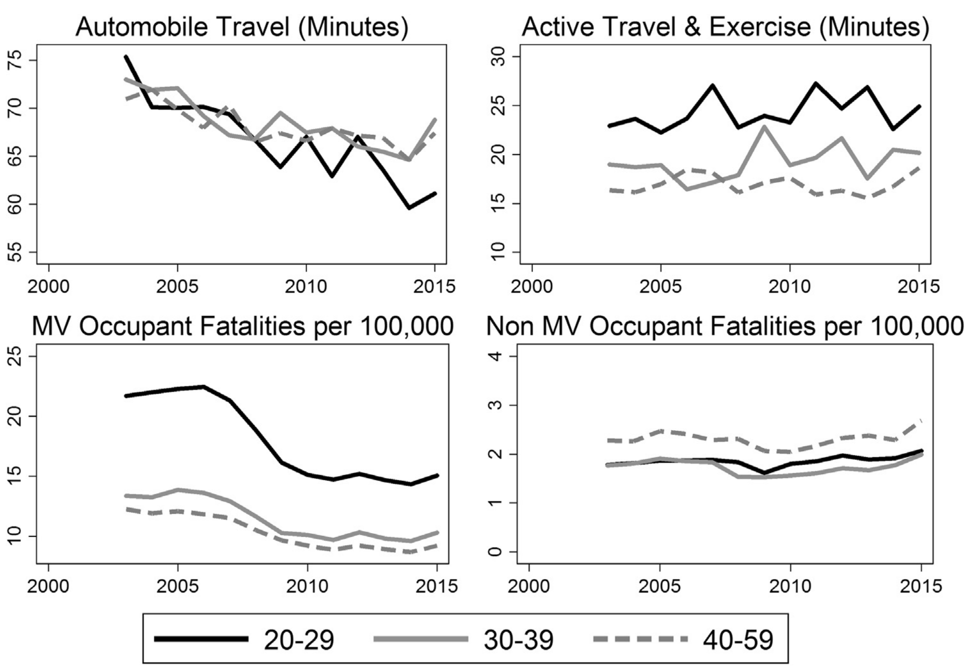

Figure 1. Automobile travel, active travel, and sports/exercise, and fatality rates by age group, 2003–2015.
MV, motor vehicle.

Table 2. Minutes of Auto Travel, Active Travel, Other Sports, and Total Activity by Age Group, 2003–2014

	Daily minutes		Absolute difference		Unadjusted linear trend		Adjusted linear trend[a]	
Age group	**2003**	**2014**	**Δ**	***p*-value**	**Δ**	***p*-value**	**Δ**	***p*-value**
Auto travel								
20–29 years	75.4	59.6	−**15.7**	<0.001	−**11.5**	<0.001	−**10.1**	<0.001
30–39 years	73.0	64.6	−**8.4**	<0.001	−**7.5**	<0.001	−**5.6**	<0.001
40–59 years	70.9	64.6	−**6.3**	<0.001	−**5.5**	<0.001	−**3.9**	0.001
All, 20–59 years	72.5	63.3	−**9.2**	<0.001	−**7.5**	<0.001	−**5.8**	<0.001
Utilitarian active travel								
20–29 years	4.1	3.6	−0.5	0.457	-0.3	0.434	−0.8	0.063
30–39 years	3.2	3.0	−0.2	0.705	-0.1	0.750	−**0.8**	0.022
40–59 years	2.3	2.4	0.2	0.591	-0.2	0.413	−**0.6**	0.003
All, 20–59 years	3.0	2.9	−0.1	0.757	-0.2	0.293	−**0.7**	<0.001
Leisure active travel								
20–29 years	1.9	2.5	0.6	0.332	**1.1**	0.021	**0.9**	0.050
30–39 years	2.3	2.7	0.3	0.587	**0.8**	0.026	0.6	0.102
40–59 years	3.1	3.8	0.7	0.162	0.2	0.537	0.0	0.930
All, 20–59 years	2.6	3.2	0.6	0.099	**0.6**	0.011	0.4	0.094
Sports and exercise								
20–29 years	17.0	16.5	−0.5	0.816	1.1	0.518	1.1	0.527
30–39 years	13.5	14.8	1.4	0.414	1.2	0.314	1.6	0.210
40–59 years	11.0	10.5	−0.5	0.642	−0.8	0.269	−0.2	0.803
All, 20–59 years	13.1	13.1	0.0	1.000	0.2	0.712	0.7	0.315
Total active travel and exercise								
20–29 years	22.9	22.6	−0.3	0.882	1.9	0.320	1.2	0.528
30–39 years	19.0	20.5	1.5	0.404	2.0	0.142	1.4	0.291
40–59 years	16.4	16.7	0.4	0.773	−0.8	0.361	−0.8	0.350
All, 20–59 years	18.6	19.1	0.5	0.636	0.6	0.404	0.4	0.646

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Adjusted models control for sex, age, race/ethnicity, housing tenure, presence of children in household, employment, location in region.

rates were much lower and were level during the study period (Figure 1).

Declines in population-adjusted death rates for motor vehicle occupants were significant for all age groups and largest for young men (Table 3). Changes in population-adjusted fatalities for non-motor vehicle occupants were not significant, with the exception of women aged 20–29 years ($\Delta=0.3$, $p<0.001$) and men aged 30–39 years ($\Delta=-0.3$, $p=0.002$). Exposure-adjusted death rates for motor vehicle occupants decreased over the study period, but the drops were smaller in absolute and relative terms compared with population-adjusted rates. For young men, the CIs on the exposure-adjusted death rates suggested no significant difference between 2003 and 2014 (Table 4).

DISCUSSION

Consistent with previous research and federal statistics, this analysis shows a drop in automobile travel from 2003 to 2014 with the largest decreases among young adults, particularly men.[6,32,33] Despite predictions to the contrary, a substantial decline in auto use has not been accompanied by an increase in time spent in active travel nor in reallocating travel time to exercise. Minutes of utilitarian active travel, leisure active travel, and participation in sports and exercise were largely unchanged. These results accord with analyses from the transport literature that show the drop in driving occurred because Americans were going fewer places not because they were switching from cars to travel by bus, foot, or bicycle.[6] Americans have stayed home more in the recent decade for a complex set of inter-related factors. Technologic advances have eliminated the need for some face-to-face interaction.[34] High gas prices, rising debt, stagnant incomes, and increases in unemployment have made driving more costly during parts of the study period.[3,4] Finally, delays in employment, partnering, and parenthood have lowered the need for certain types of trips.[6]

Fatalities to motor vehicle occupants dropped significantly during the study period, particularly among

Table 3. Population-Adjusted Death Rates for Motor Vehicle Occupants, 2003–2014

Occupants	Population-adjusted death rate per 100,000 population					
					Linear trend[a]	
	2003	95% CI	2014	95% CI	Δ	*p*-value
20–29 years						
Male	32.1	31.3, 32.9	21.0	20.4, 21.6	−**15.3**	<0.001
Female	10.9	10.5, 11.4	7.4	7.0, 7.7	−**4.4**	<0.001
Total	21.7	21.2, 22.1	14.3	14.0, 14.7	−**9.9**	<0.001
30–39 years						
Male	19.5	18.9, 20.1	14.5	13.9, 15.0	−**7.0**	<0.001
Female	7.2	6.9, 7.6	4.8	4.5, 5.1	−**3.1**	<0.001
Total	13.4	13.0, 13.7	9.6	9.3, 9.9	−**5.0**	<0.001
40–59 years						
Male	17.4	17.0, 17.9	13.0	12.6, 13.3	−**5.4**	<0.001
Female	7.2	7.0, 7.5	4.5	4.3, 4.7	−**3.1**	<0.001
Total	12.2	12.0, 12.5	8.7	8.5, 8.9	−**4.2**	<0.001
20–59 years						
Total	14.8	14.7, 15.0	10.4	10.2, 10.5	−**5.8**	<0.001

Note: Boldface indicates statistical significance ($p < 0.05$).
[a]Linear trend from state-level fixed effects model with annual data from 2003–2014. Linear trends not computed for exposure-adjusted death rates because state-level estimates are not available.

millennials. Many factors could explain this decline, including improved driver safety training, such as graduated driver licenses, safer vehicles, and enhanced enforcement of device restrictions while driving. But, the decrease could also be explained by the large and significant drop in driving. Analyses of exposure-adjusted death rates show small declines, suggesting that decreased exposure explains much of the decline in the population-adjusted death rate. For example, the population-adjusted death rate for young men decreased by 35% between 2003 and 2014 whereas the exposure-adjusted rate dropped by 10%.

Questions remain about the durability of these declines in fatalities. Driving and fatalities increased in 2015 and the continued low cost of gas along with the economic recovery suggest auto travel will increase (Figure 1). Safety researchers and practitioners will be challenged by rising automobility in their efforts to make America's roads safer. From a public policy perspective, this means efforts to reduce fatalities through driver

Table 4. Exposure-Adjusted Death Rates for Motor Vehicle Occupants, 2003–2014

Occupants	Exposure-adjusted death rate per 1 million minutes auto travel			
	2003	95% CI	2014	95% CI
20–29 years				
Male	10.9	10.0, 11.7	9.7	8.7, 10.8
Female	4.3	4.0, 4.6	3.4	3.0, 3.7
Total	7.9	7.4, 8.3	6.6	6.1, 7.0
30–39 years				
Male	6.9	6.5, 7.3	6.1	5.6, 6.7
Female	2.9	2.7, 3.1	2.0	1.8, 2.2
Total	5.0	4.8, 5.2	4.1	3.8, 4.3
40–59 years				
Male	6.7	6.4, 6.9	5.4	5.0, 5.8
Female	2.8	2.7, 3.0	2.0	1.8, 2.1
Total	4.7	4.6, 4.9	3.7	3.5, 3.8
20–59 years				
Total	5.6	5.5, 5.7	4.5	4.3, 4.6

training and vehicle technology, as well as roadway and community design, will become even more critical. Opportunities may also exist to maintain lower levels of driving among young adults, where evidence of licensure delay and lifestyle shifts may limit driving increases. From a safety perspective, this is critical because young adults, particularly men, have high fatality rates.

Limitations

The primary metric of physical activity used in this analysis is time. This ignores possible changes in the intensity of walking, bicycling, and sports participation. Although it is unlikely that the intensity of utilitarian and leisure active travel would change substantially over time, it is possible that the average intensity of sports and exercise participation could change. Additionally, this analysis did not consider all possible sources of physical activity but rather focused on sources of activity with a logical connection to decreased driving. A final caveat is that ATUS does not include indivuduals living in group quarters, such as university dorms and military barracks. Therefore, the results are representative of adults not living in group quarters. However, estimates of those living in university residence halls suggest that no more than 5% of adults aged 20–29 years would be excluded for this reason.

CONCLUSIONS

This analysis shows that the decline in driving in the recent decade has been associated with public health benefits from decreases in traffic fatalities to motor vehicle occupants. However, physical activity from active travel, sports, and exercise did not increase contrary to previous predictions. The drop in driving and the decrease in fatalities have been most prominent among millennials, particularly men. In 2015, driving and fatalities increased, highlighting the challenges facing safety practitioners.

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