The Fatality Risk of Walking in America: A Time-Based Comparative Approach

Xuehao Chu

Abstract

This paper proposes a time-based comparative approach to examining the fatality risk of walking. This approach is comparative in that it looks at the fatality risk of walking in relation to that of vehicle travel. This approach is time-based in that it uses a time-based measure of exposure to determine fatality risks. This approach is applied to the United States for 2001. Fatality risk is stated in terms of the number of deaths per 10 million person hours traveled. Exposure is estimated with self-reported data on trip duration from the 2001 National Household Travel Survey (NHTS), while data on the number of deaths are from the 2001 Fatal Analysis Reporting System (FARS). Time walked includes travel not only for utilitarian purposes (e.g., shopping) but also for exercise, for walking a dog, and for access to or egress from another mode. Vehicle travel is limited to passenger vehicles, including cars, vans, sports utility vehicles, and pickup trucks. Problems of traditional approaches are shown. Several applications of this time-based comparative approach are illustrated. Recommendations are made on future research to improve data collection for this time-based comparative approach. (186 words)

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Introduction

Current practices in examining the fatality risk of walking in the United States commonly use a population-based measure of fatality risk. The U.S. Federal Government, for example, uses population as exposure for measuring the fatality risk of walking in the nation (National Highway Traffic Safety Administration various years). One advantage of the population-based measure is that relatively good data are available on an annual basis for various geographic levels. The disadvantages, however, overweigh this advantage. A population-based approach is inadequate in general and can be misleading in some cases for problem identification or policy development.

Furthermore, current practices largely use the population-based measure in isolation. It is important to know how safe it is to walk and whether walking is getting safer over time. It is equally, if not more important, to know whether walking is as safe as riding in a passenger vehicle and whether walking is getting more dangerous over time relative to riding in a passenger vehicle. Nationwide walking and riding in a passenger vehicle are the most used modes for local person travel. Some may argue against equal modal risk as a policy objective (Hakkert and Braimaister 2002). A case may be made, however, for the desirability of equal risk between walking and riding in a passenger vehicle. Some people walk because they choose to do so. Some of these may have chosen not to own a passenger vehicle. Others may have vehicles available but choose to walk for some of their travel. On the other hand, there are people who walk because they have little choice of alternative modes. These are largely captive walkers. While risk of riding in a passenger vehicle has been declining considerably over the last several decades, it is the captive walkers who have been adversely affected by the increased exposure to vehicle traffic (Erskine 1996). As society as a whole has chosen to invest in providing transit services substantially subsidized for captive transit users, one might reasonably evaluate whether or not the current investment is appropriate or equitable in supporting captive walkers. After all, more activities are accomplished by walking than taking transit in the United States.

One reason for the current use of this population-based stand-alone approach is that we have not had adequate data to support an alternative approach. This is particularly the case with respect to exposure measurement for walking. The U.S. Bureau of Transportation Statistics recently assesses state of the art for measuring exposure of walking (Bureau of Transportation Statistics 1998):

> "Analyses of safety trends for nonmotorized modes—bicycling and walking—suffer from the absence of exposure measures (such as hours of exposure to traffic).

> Moreover, bicyclists and walkers often take trips too short in length to be counted in national travel surveys. Furthermore, trips that begin and end at a residence, without an intermediate stop, are typically not counted, thus excluding much recreational bicycling and walking."

The newly released National Household Travel Survey (NHTS) provides a unique opportunity to examine the fatality risk of walking in the United States with a time-based comparative approach. On walking, for example, the 2001 NHTS made a particular effort to avoid the other two problems mentioned in this assessment. The questionnaire included multiple prompts on including trips by walk or bike and trips that started and ended in the same place (Department of Transportation 2003). These reminders have significantly increased the completeness of walk-trip reporting. A good indication of this increase is that the annual number of walk trips nationwide jumped by 73.8 percent from 20,325 million in the 1995 NPTS to 35,326 million in the 2001 NHTS. Around 40 percent of the jump may have resulted from including trips that start and end at the same place without an intermediate stop. Given the recent trends in nationwide walking, most of this jump is likely to have resulted from better reporting. With the 2001 NHTS, exposure could include walking not only for utilitarian purposes (e.g., shopping) but also for exercise, for walking a dog, and for access to or egress from another mode. For both walking and riding in a passenger vehicle, the 2001 NHTS can be used to measure travel in terms of self-reported duration. A time-based measure of exposure is chosen over a distance-based measure because a distance-based measure suffers from its inability to account for the large speed differences between walking and riding in a passenger vehicle.

This paper has four objectives. One is to present how fatality risks are measured with the 2001 NHTS and to discuss related measurement issues. The second objective is to show problems with the population-based stand-alone approach and others for safety analysis. The third is to illustrate several applications of the time-based comparative approach. The last objective is to recommend areas of further research to improve data collection efforts for this time-based comparative approach.

Time-Based Comparative Approach

This section discusses how the absolute fatality risks are measured for both walking and riding in a passenger vehicle. In addition, it examines several measurement issues that could affect the comparative risks between the two modes.

Risk Measurement

We use the 2001 data from the Fatal Analysis Reporting System (FARS) to measure the number of deaths. FARS contains the annual census of all fatal crashes on public roads in the United States (National Center for Statistics and Analysis 2003). Deaths occurred at the scene of a crash or within 30 days of the crash are included. Crashes are identified with a number of factors, including state, county, month, day of week, and time of day. Persons involved, including those who died, are identified with gender, age, and whether they were on foot or occupants of a motor vehicle. Beginning with the 2001 data, FARS also identifies the race and ethnicity of persons involved. Compared with other identification information,

however, data are missing on race and ethnicity for 43.3 percent of the persons in the 2001 FARS. Occupants of a motor vehicle are further identified with the type of motor vehicles they were riding in. To better match person travel by motor vehicles for exposure measurement, we only include cars (1-11), vans (20-22, 28-29), sports utility vehicles (14-19), and pickup trucks (30-39, 67), where the numbers are the codes for body type used in FARS (Tessmer 2002).

We use the 2001 NHTS to measure the number of hours traveled. It is the only authoritative source of local person travel at the national scale (Department of Transportation 2003). The 2001 NHTS collected data about one-way trips taken during a designated travel day by a national random sample of 26,028 households. A one-way trip is defined as any time a subject went from one address to another for purposes other than changing the type of transportation. The information about these one-way trips includes the time the trip began and ended, length of the trip, duration of the trip, composition of the travel party, mode of transportation, and purpose of the trip. If more than one mode is used on a one-way trip, the mode covered the most distance is designated as the main mode for that trip. Data collected include travel by persons of all ages. The travel days were assigned to all days of the week and all seasons from April 2001 through April 2002. The travel day started at 4:00 am of the day assigned and continued until 3:59 am of the following day. Travel data were collected through telephone interviews to get information on pre-mailed travel diaries. In addition to travel activities, data were also collected on household and member characteristics, on the characteristics of the geographic areas in which these households are located, and the typical number of walk and bike trips made over a week. The survey has also developed weights to expand the sample to national annual totals. Note that data were collected for more than a year and that some of the data are for travel during 2002. In the interest of keeping the sample as large as possible, we do not limit our analysis to the 2001 months of April through December.

To more fully capture all walking, we include walking for access to or egress from the main mode of a trip. The 2001 NHTS includes several pieces of information on access to and egress from this main mode. There are up to five modes for access and egress, respectively. These modes, however, are not necessarily recorded in their temporal order. In addition, the total amount of time taken for all access modes combined is also collected. Similarly, there is information on the total amount of time taken for egress. Access or egress occurs not just for trips whose main mode is public transportation but also other modes such as carpooling. We choose to limit to those trips that used walking as the sole access or egress mode. These trips represent about 85 percent of all trips that involve some access modes and 81 percent of all trips that involved some egress modes. There are no trips that involved more than three access or egress modes. We believe that this approach leaves out little access and egress walking.

Table 1 shows the distribution of walking for access/egress, exercise, walking a dog, and utilitarian purposes. The distribution is shown for both the number of walks and the amount of time. The terminology “walks” is used because the walks for access or egress are not trips according to the 2001 NHTS. The relative shares of the different components of walking differ between walking being measured in walks or in time. The share of walking for

access/egress decreases from 26.2 percent in terms of walks to about 14.2 percent in terms of time. Walks for access/egress are typically shorter than utilitarian walks. On the other hand, the share of walking for exercise increases from 10.5 percent in terms of walks to 24.3 percent in terms of time, reflecting that fact that exercise walks are typically much longer than others.

Table 1. Distribution of Annual Walking Across Purposes by Measurement, 2001 U.S.

Purposes	Number of Walks (Percent)	Number of Minutes (Percent)
Access/Egress	26.2	14.2
Exercise	10.5	24.3
Walking a Dog	2.2	3.5
Utilitarian	61.0	58.0
All	100	100

(Sources: Estimated by the author from the 2001 NHTS)

Previous Efforts

Measuring risk by time exposure has long been used in a comparative approach. Jonah and Engel (1983) measure the risk of crash involvement for walking by time traveled along with several other exposure measures. Data for exposure are based on self-reporting surveys in Canada. Anderson *et al*. (1989) compare time-based fatality risks between walking, riding as a passenger, and driving in Australia for 1984-1985. Keall (1995) measures the risk of injuries for walking by time traveled for age and gender groups, using the 1989-1990 New Zealand Travel Survey. More recently, the U.K. Department of Environment Transport and the Regions (1998) and the European Transport Safety Council (1999) both use a time-based measure to compare risk levels between walking and riding in a passenger vehicle. The author is unaware of any previous efforts, however, to estimate time-based risk measures at the national level in the United States. Much of this body of work, however, does not go beyond a simple comparison of the fatality risks of walking versus riding in a passenger vehicle.

Measurement Issues

A number of issues could affect the measurement of risks. Some of these have clear impacts on the relative risks. First, the current measure uses perceived time for both walking and riding in a passenger vehicle. Relative to riding in a passenger vehicle, people may perceive time spent on walking longer than it actually is. That is one reason why people value time spent walking more than time spent in a motor vehicle. To the extent that this is true, the current measure would underestimate the risk of walking.

Second, the current measure relies on self-reported data. Walking may be under-reported in self-reported data for two reasons: forgetting and purposely choosing not to report. Both of these reasons are related to the fact that walking trips are relatively short. These very short trips may not register in the memory of respondents or the respondents may think that these short trips are unimportant. Under-reporting of walking would overestimate the risk of walking. As discussed in the introduction, however, under-reporting of walking is likely to be insignificant in the 2001 NHTS.

Third, the current measure uses time spent by passenger vehicle occupants on all functional facilities, including interstates and other freeways. While walking is largely done off interstates and other freeways, a large share of motoring is done on the interstates and freeways. For riding in a passenger vehicle, the interstates and freeways have far lower fatality risks than local roads. In addition, speeds on interstates and freeways are also much higher overall than on local roads. As a result of these two factors, our measure would underestimate the fatality risk of riding in a passenger vehicle on local roads. This degree of underestimation is likely to vary across population groups, however, depending on their differences in travel speed and percent of vehicle travel between local roads and freeways.

More important, the nature of time spent can differ dramatically between walking and riding in a passenger vehicle. On one hand, almost all time spent riding in passenger vehicles represents real exposure to risk. This is true even if other traffic is not present because a large share of occupant fatalities results from single-vehicle crashes. On the other hand, walking may be done along off-road trails or even in the woods for exercise purposes. Except the portion between the origin and the start of a trail, off-road walking has little exposure to vehicle traffic. Furthermore, only a small portion of time spent walking may represent real exposure to vehicle traffic. This portion would include time spent crossing roads, walking on road surface, or possibly walking along roadside where there are no curved sidewalks. Recent data from Paris, France indicate that this portion may be as low as 10 percent of all time spent walking (Julien and Carré 2002). These include walking to and from other modes, time spent walking within the public transportation system (e.g., stairs and platforms in stations), and many others. As a result, the current measure using the 2001 NHTS would underestimate the fatality risk of walking by as much as ten fold.

Other issues can influence the measurement of absolute risks but their effect on the relative risks is unclear. First, the current release of the 2001 NHTS includes local person travel but not long-distance travel or local travel done at a vacation destination. At the same time, the 2001 FARS includes all deaths from vehicle crashes in the nation. Thus, exposure would be underestimated for both walking and riding in a passenger vehicle. Second, the number of deaths is largely an actual value from the 2001 FARS. This is especially true at the national level for all deaths combined. At disaggregate levels, there are missing values associated with certain characteristics of persons involved such as person age and gender as well as certain characteristics of the crashes such as time of day. On the other hand, the amount of travel for both walking and riding in a passenger vehicle is estimated from a national sample. There are sampling errors as a result on the estimated amount of travel for both modes. Furthermore, the sampling errors are likely to be larger for walking because of the relatively smaller number of walking trips involved. However, the potentially larger sampling errors for walking can affect the exposure estimates in either direction.

Inadequacy of Current Practices

This section shows problems with approaches used in current practices. One is the population-based stand-alone approach. One is the population-based comparative approach. The other is the distance-based comparative approach.

Population-Based Stand-Alone Approach

The number of deaths per100,000 population is often used in isolation for comparing the fatality risk of walking across geographic areas or across population groups at a given time. As an indication of the problems for spatial comparison, we calculate the correlation coefficient between our time-based measure and the population-based measure of the fatality risk for walking at the individual state level. The resulting correlation coefficient is 0.69 for 2001. This problem of the population-based measure results from the relatively large variations in per capita walking across the states. In fact, the coefficient of variation of per capita walking across the states, i.e., the ratio of the average to the standard deviation is 0.49. Similarly, it provides a poor comparison across population groups because per capita walking varies cross these groups as well (Table 2).

Table 2. 2001 U.S. Annual Per Capita Minutes Traveled by Mode, Age, and Gender

Person	Walking			Riding in a Passenger Vehicle		
Age	Male	Female	All	Male	Female	All
Under 15	2,022	2,029	2,025	15,588	15,896	15,739
15-19	2,986	2,377	2,692	19,200	21,603	20,359
20-79	1,996	2,304	2,156	28,791	25,407	27,038
80+	1,422	1,159	1,257	18,421	11,867	14,300
All	2,062	2,213	2,139	24,818	22,704	23,736

(Sources: Computed by the author from the 2001 NHTS)

The population-based stand-alone approach, however, seems to be reasonable when used for comparing the fatality risk of riding in a passenger vehicle across geographic areas. The correlation coefficient between our time-based measure and the population-based measure of the fatality risk across states is 0.97 for riding in a passenger vehicle, which is much higher than 0.69 for walking. The reason is that the variation in per capita riding in a passenger vehicle across states is small with a coefficient of variation of only 0.10, compared to 0.49 for walking.

It is even possible that the wrong conclusion is drawn on the fatality risk trend of walking when the population-based measure of risk is used for that purpose. The population-based measure of fatality risk for walking may be declining over time but the time-based measure is actually increasing. This could happen, for example, if per capita walking declines faster than the population-based measure of fatality risk.

Population-Based Comparative Approach

The population-based comparative approach is largely meaningless when used for comparing fatality risks between walking and riding in a passenger vehicle at a given time. The fact that the population-based fatality rate is 1.7 deaths per 100,000 population for walking versus 12.7 deaths per 100,000 population for riding in passenger vehicles does not mean that walking is 87 percent safer than riding in a passenger vehicle. In fact, we could not even tell if walking is actually safer. The reason for this is that people spend far more time riding in a passenger vehicle than walking in the United States (Table 2).

The population-based comparative approach has equally serious problems for comparing the trends in fatality risk between walking and riding in a passenger vehicle for a given population. Table 3 shows the U.S. trends from 1980 to 2000 in the population-based fatality rate for both walking and riding in a passenger vehicle. If used as measures of fatality risk, these numbers would indicate that the fatality risk of walking has become more than that of riding in a passenger vehicle. While we do not have direct evidence, we believe that walking has become less safe than riding in a passenger vehicle in the United States. We do have evidence from Great Britain, however. With time-based fatality risks for both walking and riding in a passenger vehicle, walking was about 9 percent safer than riding in a passenger vehicle in 1976 but in 1996 it had become more dangerous by 51 percent (Department of Environment Transport and the Regions 1998). The problem in this case with the population-based comparative approach is that the population-based measure fails to take into account differential trends in per capita walking versus riding in a passenger vehicle over time. Again we do not have direct evidence for the U.S. In Great Britain during the period from 1976 to 1996, the annual number of hours traveled per capita decreased from 99 to 81 for walking but increased from 132 to 204 for riding in a passenger vehicle (Department of Environment Transport and the Regions 1998).

Table 3. U.S. Trends in Population-Based Fatality Rates between Walking and Riding in a Passenger Vehicle, 1980-2000

	1980	1990	2000	% Change (1980-2000)
Deaths of Walkers	8,070	6,482	4,739	-41
Deaths of Occupants (Passenger Vehicles)	27,449	24,092	20,492	-25
Population	227,225	249,464	274,634	21
Deaths of Walkers/100,000 Population	3.552	2.598	1.726	-51
Deaths of Occupants/100,000 Population	12.080	9.658	7.462	-38

(Sources: Estimated by the author with data from Department of Transportation (2001))

Distance-Based Comparative Approach

Relative to the population-based measure of fatality risks, a distance-based measure would be an improvement. Typically it is stated in terms of the number of deaths per 100 million person miles traveled. While this measure avoids the problem that the population-based measure faces, it has a different problem. Because of speed differences between walking and riding in a passenger vehicle, one person-mile of walking represents far more exposure to vehicle traffic than one person-mile of riding in a passenger vehicle. Thus, using a distance-based measure of fatality risk would inflate the risk many times for walking. Evidence from Great Britain indicates that the inflation can result in the ratio of relative risks between walking and riding in passenger vehicles over ten times (Department of Environment Transport and the Regions 1998).

Potential Applications

Three potential applications are discussed. The basic application of the time-based comparative approach would be simply to compare the relative fatality risks between walking and riding in a passenger vehicle as the previous efforts have done for other countries. However, the time-based comparative approach can be used as part of a toolbox for problem identification and policy development. In addition to comparing risks, it may be used to identify problem areas for further analysis and to assess the role of the transportation infrastructure in the relative fatality risk of walking.

Danger of Walking

The time-based comparative approach can be used to show the danger of walking relative to riding in a passenger vehicle at a variety of levels. This section shows the comparison at the U.S. national level. We tabulate from the 2001 data of FARS that a total of 4,882 walkers died from being involved in vehicle crashes that occurred during 2001 (Table 4), compared to a total of 31,785 occupants of passenger vehicles. At the same time, we estimate with the 2001 NHTS that Americans walked 9,982.4 million hours for local travel, compared to 109,662.4 million hours riding in a passenger vehicle for local travel. The nationwide fatality rate for 2001 is estimated to be 4.94 deaths per 10 million hours for walking and 2.90 deaths per 10 million hours for motoring. These result in a relative walking to motoring risk ratio of 1.70. That is, walking was 70 percent more dangerous than motoring in the United States during 2001.

Table 4. U.S. Fatality Risks of Walking and Riding in Passenger Vehicles in 2001

Deaths of Walkers	4,882
Deaths of Occupants	31,785
Time Walked (Million Hours)	9,982.4
Time Rode (Million Hours)	109,662.4
Walking Risk (Deaths/10 Million Hours)	4.94
Motoring Risk (Deaths/10 Million Hours)	2.90
Ratio of Walking to Motoring Risks	1.70

(Sources: Estimated by the author from 2001 NHTS and 2001 FARS)

To put these absolute risks in perspective, they are compared with the odds of winning the Florida Lotto with the odds of someone being killed while completing a 30-minute walk. According to the official website of Florida Lottery (2003), the odds of winning the Florida Lotto is about 1: 23 million. In comparison, Table 5 shows the odds of someone being killed while taking a half-hour walk under a full range of risk scenarios. At one extreme with the risk of 1 death per 10 million hours walked, a female of average age taking a half-hour walk in the early afternoon hours is more likely to be killed by a motor vehicle than to win the Florida Lotto. At the other extreme with the risk of 400 deaths per 10 million hours walked, a person of average gender and age taking a walk between 3:00 AM and 4:00 AM has a chance of 1 to 50,000 to not survive the walk.

Table 5. Odds of Being Killed for a Half-Hour Walk by Scenario

Scenario			Risk (Deaths/10 million hours)	Odds
Time of Day	Gender	Age		
Early Afternoon	Female	All	1	1: 20,000,000
Daily Average	Male	35-49	10	1: 2,000,000
Daily Average	All	84+	40	1: 500,000
3:00AM-4:00AM	All	All	400	1: 50,000

(Sources: Estimated by the author)

We also compare these risks with those from Europe (Table 6). Look at relative risks first. Both walking and riding risks declined in Great Britain during the period from 1976 to 1996. As indicated earlier, however, the relative risk between walking and riding in a passenger vehicle increased from 0.91 in 1996 to 1.51 in 1996. Based on a linear extrapolation, the relative walking to riding risk is estimated to be around 1.66 in Great Britain during 2001, versus 1.70 in the U.S. in the same year. The difference in relative walking to riding risks is much larger from the European Union, however (1.70 versus 1.0). In terms of absolute risks, the U.S. is much less favorable compared to Great Britain. Riding in a passenger vehicle is about twice as dangerous in the U.S. as in Great Britain (2.90 versus 1.52), while walking is about two and a half times as dangerous in the U.S. (4.94 versus 2.29). Compared to the European Union as a whole, on the other hand, walking is still far more dangerous in the U.S. (4.94 versus 3.00) but motoring is slightly safer (2.90 versus 3.00).

Table 6. Comparing Relative Walking and Riding Risks

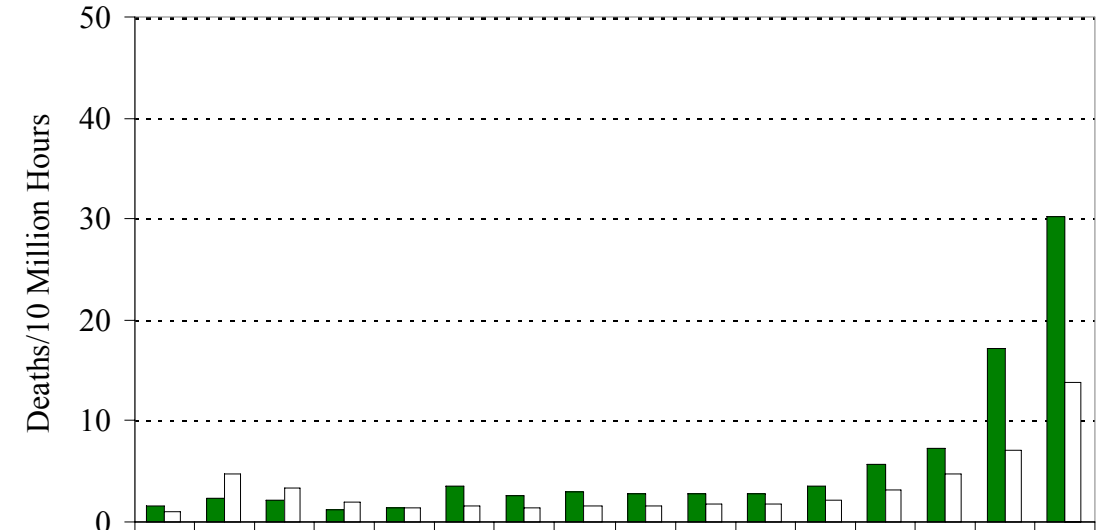
Region	Year	Walking Risk (deaths per 10 million hours)	Riding Risk (deaths per 10 million hours)	Ratio of Walking to Riding Risks
United States	2001	4.94	2.90	1.70
European Union	1999	3.00	3.00	1.00
Great Britain	1996	2.29	1.52	1.51
Great Britain	1976	4.32	4.77	0.91

(Sources: The U.S. numbers are estimated discussed earlier; data for the European Union are from European Traffic Safety Council (1999); and data for Great Britain are from the U.K. Department of Environment Transport and the Regions (1998))

Problem Identification

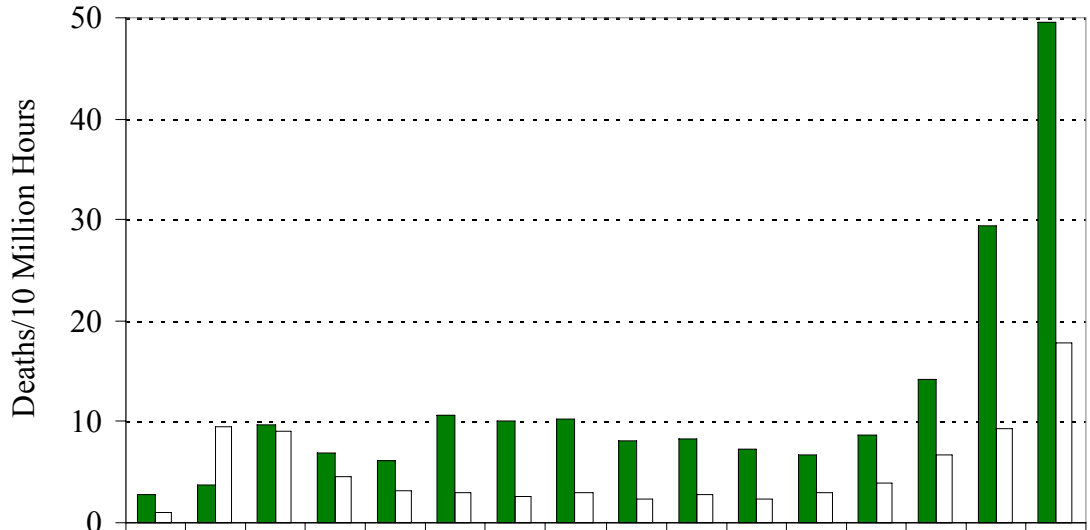
The time-based comparative approach may be used to identify potential problem areas for walking. The strategy is to compare the relative risks between walking and riding across population groups. The objective is to identify groups for which walking is particularly more dangerous in absolute terms than riding in a passenger vehicle. Figure 1 compares the relative risks between age cohorts for female. Figure 2 is a similar graph for male. One

question is this: In comparison with other age cohorts, why is the fatality risk of walking for the cohorts of 80 years or older significantly higher in absolute terms than their fatality risk of riding in a passenger vehicle? This gap of fatality risks between walking and riding among the oldest cohorts is even larger for male than for female.



	<15	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	>84
Walking	1.5	2.3	2.2	1.3	1.4	3.6	2.6	2.9	2.7	2.8	2.8	3.5	5.7	7.3	17.2	30.2
Riding	0.9	4.7	3.4	2.0	1.3	1.7	1.4	1.5	1.5	1.8	1.7	2.1	3.1	4.7	7.2	13.9

(Sources: Estimated by the author from 2001 NHTS and FARS)
Figure 1. Female Fatality Risks by Mode and Person Age, 2001 U.S.

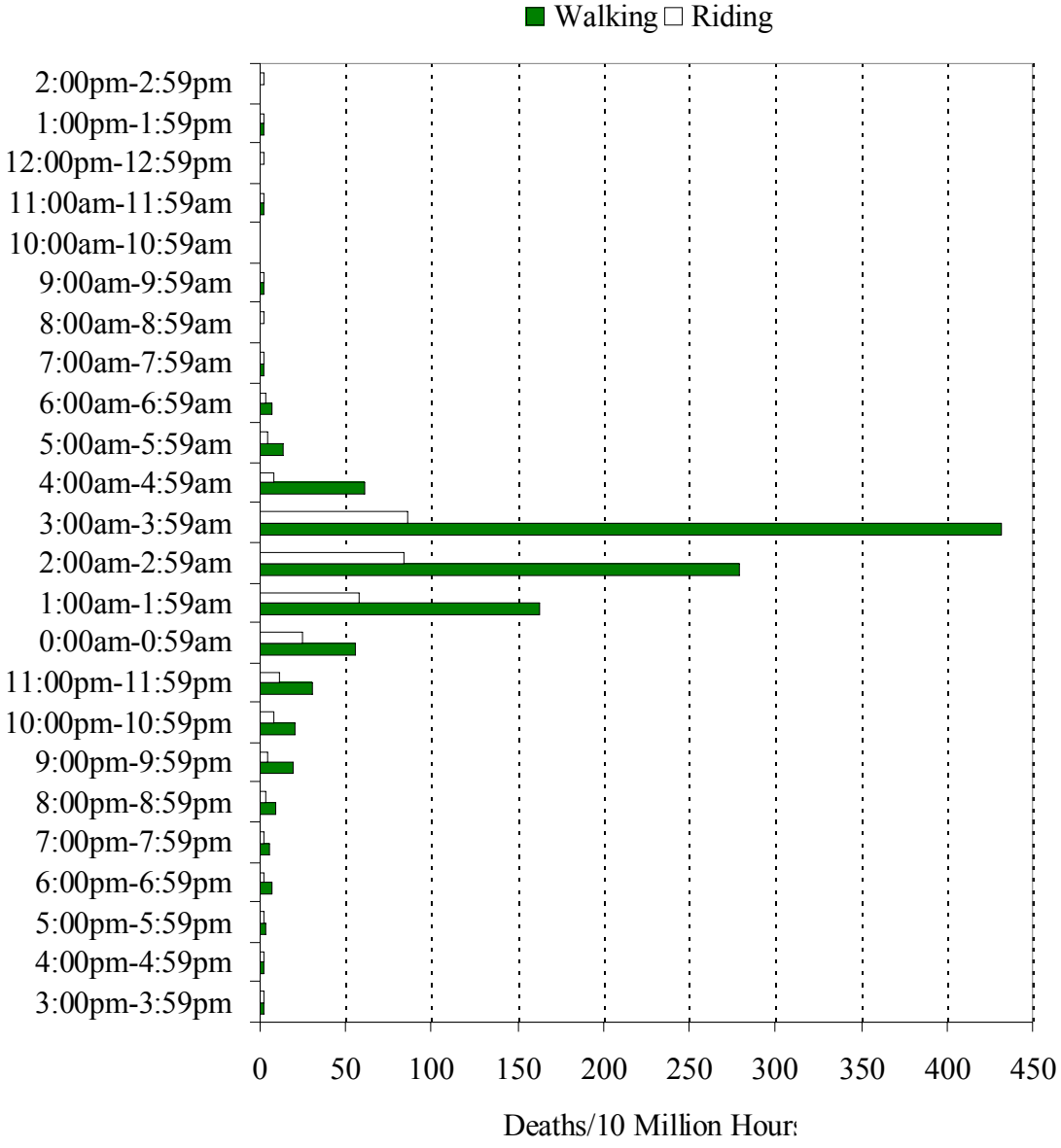


	<15	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	>84
Walking	2.7	3.8	9.8	6.9	6.2	10.7	10.0	10.2	8.1	8.4	7.4	6.8	8.6	14.1	29.4	49.7
Riding	0.9	9.4	9.0	4.6	3.1	3.0	2.6	3.0	2.5	2.7	2.4	2.9	4.0	6.7	9.3	17.8

(Sources: Estimated by the author from 2001 NHTS and FARS)
Figure 2. Male Fatality Risks by Mode and Person Age, 2001 U.S.

Role of the Transportation Infrastructure

The time-based comparative approach may be used to assess the role of the temporally fixed portion of the transportation infrastructure in the elevated fatality risk of walking relative to riding in a passenger vehicle observed earlier. By temporally fixed we mean the portion of the transportation infrastructure that stays the same between daytime and nighttime. It includes not only walking-specific facilities (e.g., sidewalks, crosswalks, walking signals) but also facilities and regulations that restrain vehicle traffic and are designed to benefit walking (e.g., traffic calming).



(Sources: Estimated by the author from 2001 NHTS and FARS)
Figure 3. Absolute Risks of Walking and Riding by Time of Day

Figure 3 shows the absolute risks for both walking and riding by hour of day. During the 10 daytime hours between 7:00AM to 5:00PM, walking is as safe as riding. During the other hours, however, walking can be as high as five or eight times as dangerous as riding. This finding of equal risk between walking and riding is reinforced by the fact that riding in a passenger vehicle is also the safest in a day during the hours from 7:00AM through 5:00PM. As shown earlier, walking is more dangerous overall than riding in a passenger vehicle. The evidence from this figure shows that it is not the temporally fixed portion of the transportation infrastructure that makes walking more dangerous than riding. Rather it is some of the differences in our transportation system between day and night that make walking more dangerous than riding in a passenger vehicle. Some of these differences

include light conditions, traffic density, the behavior of both walkers and vehicle occupants (e.g., drunkenness), and levels of law enforcement and emergency services.

Conclusion and Future Research

The time-based comparative approach provides a more effective tool than traditional approaches to problem identification and policy development for improving walking safety. Future research should explore means to solve several common problems in measuring the fatality risks of walking and other modes. Two are discussed below.

One problem relates to the lack of time-based exposure data for riding in passenger vehicles by functional classification of roads. Our exposure data for walking includes little if any travel on limited-access highways, while our exposure data for riding in passenger vehicles includes travel on roads of all functional classifications. Relative to the risk of walking, our measure overstates the fatality risk of riding in passenger vehicles on local roads.

The other problem relates to the failure of time-based exposure data for walking to account for differences in the nature of time traveled between walking and riding in passenger vehicles. On one hand, almost all time spent on riding in passenger vehicles represents real exposure to risk. This is true even if other traffic is not present because a large share of occupant fatalities results from single-vehicle crashes. In contrast, walking may be done along off-road trails or even in the woods for exercise purposes. Except the portion between the origin and the start of a trail, off-road walking has little exposure to vehicle traffic. Furthermore, only a small portion of time spent on on-road walking may represent real exposure to vehicle traffic. This portion would include time spent crossing roads, walking on road surface, or possibly walking along roadside where there are no curved sidewalks. If recent data from Paris are any indication, failure to account for this differential nature of time spent traveling between walking and riding in passenger vehicles would underestimate the fatality risk of walking by as much as ten fold.

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