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THE 55 MPH HIGHWAY SPEED LIMIT REVISITED:

A CASE-CONTROL STUDY

By

GROVER K. YAMANE, BA, MD

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DEDICATION

To Jill, and our two cubs, Max and Miles, for all their patience, love, understanding and support. From your Grover-bear.

And, in memory of our dear friend, Mrs. May Houghton, Isleham, United Kingdom.
THE 55 MPH HIGHWAY SPEED LIMIT REVISITED:

A CASE-CONTROL STUDY

By

GROVER K. YAMANE, BA, MD

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THE 55 MPH HIGHWAY SPEED LIMIT REVISITED:

A CASE-CONTROL STUDY

Grover K. Yamane, BA, MD, MPH
The University of Texas
Health Science Center at Houston
School of Public Health. 1998

Supervising Professor: Benjamin S. Bradshaw

Motor vehicle accidents are a significant public health problem in the US. Several host, agent, and environmental factors influence the risk of crash death. Over the past several years, maximum highway speed limits have been raised in several states. Most studies have concluded that the increased limits have increased motor vehicles deaths.

In this study, a case-control design was used to estimate the strength of association between motor vehicle driver deaths and maximum state highway speed limits in excess of 55 mph during each year in the period, 1991 to 1993. To date, no other study has used this method. Cases were obtained from the Fatal Accident Reporting System, and were grouped into three general categories of accidents: accidents not involving collisions or impacts; accidents involving collisions with other moving motor vehicles; and accidents involving collisions with stationary objects. Four separate control groups were obtained from deaths recorded in the Multiple Cause of Death Files. Decedents in the four control groups were those who died from unintentional poisoning with solids or liquids; non-Hodgkins lymphoma;
accidental drowning; or diabetes mellitus. The exposure factor was residence in a state at the time of death, according to maximum highway speed limit. Exposed cases were decedents who died in a state with a 60 or 65 mph maximum speed limit (42 states). Non-exposed cases were decedents who died in a state with a 55 mph maximum speed limit (nine states).

Controlled for age and sex, odds ratios for persons in high speed states were consistently and strongly elevated for driver deaths in non-collision accidents (adjusted OR’s = 5.6—7.1, p < 0.00000001). Also, most of the odds ratios for the other types of accidents were significantly elevated.

The study is limited by the inability to control for other geographic- or regional-related factors. Also, the two independent extant datasets did not allow for a comparison of the case and control groups beyond a few demographic factors. However, this study shows an overall association between driver deaths and states with high speed limits. Legislation concerning speed limits should consider this association, as the risks and benefits of higher speed limits are weighed.
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INTRODUCTION

Automobile crashes are a significant source of excess death and injury in the United States. In 1996, there were 41,907 fatalities and 3,511,000 injuries due to automobile crashes. More than 6.8 million crashes were reported to law enforcement agencies that year.\(^1\) Automobile crashes have ranked in the top ten causes of death for many years, and are the top cause of death for persons aged 6 to 27 years.\(^2\) The adverse economic impact of automobile crashes is likewise enormous. The U.S. Department of Transportation has estimated that crashes cost the public more than $150.5 billion in 1994.\(^3\)

Given the magnitude of the problem, even small changes in the risk of crash death can yield large absolute effects—positive or negative—over the long term. For example, a factor that produces a relatively modest 1% rise in deaths and injuries will result in an annual increase of about 400 of the former, and 35,000 of the later. Over several years, the cumulative mortality and morbidity can be tremendous.

Recently, several states have increased speed limits on their Interstate and non-Interstate highway systems. Proponents, especially from the Western states, have advocated higher limits to facilitate travel over long distances in rural areas.\(^4\) Some state law enforcement agencies have viewed liberal speed limits as an opportunity to transfer precious resources devoted to speed law enforcement towards other enforcement or traffic safety activities.\(^5\)
But, considering the urgency of the problem, there have been relatively few public health studies on automobile crashes, especially those related to highway speed limit laws. Liberalized speed laws may increase the incidence of crash deaths, and exacerbate this public health problem both in the short- and long-term. Understanding the epidemiology of automobile crash deaths and speed limits may help guide public policy decisions and legislation on traffic laws.

Despite the decreased motor vehicle-associated mortality seen during the era of the 55 mph limit,2 and concerns that higher speed driving might exacerbate crash risks, several states were eager to increase their public highway speed limits in recent years. Several states now have speed limits in excess of 65 mph; indeed, the State of Montana has altogether rescinded daytime speed limits for passenger vehicles on public highways.

There is a relatively small amount of literature on the topics of automobile crash causation and prevention, given the significance of the problem. Much of the literature is found in the more obscure publications; some of the studies have been done by economists or civil engineers, rather than by medical or public health researchers. Perhaps this lack of involvement is due to a perception in the medical community that automobile crash research and prevention is the domain of law enforcement agencies or traffic engineers. The medical community may regard automobile crash casualties in terms of trauma care, rather than a health problem that can be studied and ameliorated.

The purpose of this study is to determine the strength of the association between motor vehicle accident driver deaths and state highway speed limits, using a case-control design.
First, the literature on factors related to motor vehicle accident risk will be reviewed. Then, odds ratios will be determined using cases and controls obtained from two extant national mortality databases; the exposure factor will be maximum state highway speed limit.
REVIEW OF THE LITERATURE

Factors Related to Crashes

Several factors are related to the risk of automobile crash death. Just as with a disease, these factors may be partitioned into host, agent, and environmental categories.

- **Host Factors**

- **Driver Age**

  Age is very strongly related to the risk of automobile crashes and crash deaths. For many years, much attention has been directed toward the very young and relatively inexperienced segment of the driving population. That younger drivers carry more risk of injury and death is well known, and has been well documented. Over the past several years, injury and death rates have tended to peak for drivers in their late-teen years into their early twenties. In an analysis of the US Department of Transportation Fatal Accident Reporting System (FARS) data for 1990, Williams et al. found that the crash rate, per one million vehicle miles traveled (VMT), was 43 for 16 year old drivers, but only 5 for drivers 25 years or older. The fatality rate, per 100 million VMT, was 17 for 16 year olds, and 3 for drivers 25 years or older. The fatal crash rates, per 100,000 licensed drivers, were, respectively, 73, 60, 63, and 56 for 16, 17, 18, and 19 year olds.

  Williams et al. also examined the characteristics of fatal crashes involving the youngest drivers. Several features were more common in the 16 year old group, compared to older drivers: single-vehicle crashes, culpability for causing the crash, speeding, high vehicle occupancy (especially of teenage passengers), and a higher proportion of females.
But, alcohol use was less likely in this very young age group, probably because these
drivers were under the legal age for purchasing alcoholic beverages.6

A youth-associated risk-taking behavior syndrome has often been presented as a rea-
son for the higher crash rates among young drivers. Compared to older drivers, younger
motorists are poorer at estimating their own driving skill and in judging driving risks; they
show more dangerous driving behaviors, including speeding, following cars too closely,
and not wearing seat belts.7 But, in 1989, Groeger et al. administered questionnaires to a
group of 54 licensed British drivers of various ages to study perception of driving ability
and driving risk. Their psychologic study concluded that the higher crash risk of young
drivers may be due more to lack of driving experience, rather than to an innate age-related
tendency for risk-taking behavior.8

To reduce crash risks, several states have established driving restrictions for young,
novice drivers. These may take the form of curfews, requirements for adult supervision,
higher minimum age of licensure, or restrictions against driving on high-speed roadways.
A study by Ferguson et al. of five Eastern states concluded that those states with night-
time driving curfews and restrictions on unsupervised driving for young drivers had lower
.crash rates.9 A multivariate regression analysis by Levy found that states with increased
minimum licensing ages and night-time driving curfews had fewer fatalities among 15 to
17 year olds.10

The very oldest drivers also have a high risk of crash deaths. The crash rate, per
100,000 VMT begins to increase above 60 years of age.11 An analysis of FARS data for
1990 showed that the rate of fatal crashes, per 100 million VMT, was 9.2 for drivers aged 16-19 years; 1.8, for drivers aged 40-44 years; but, 11.5, for drivers aged 75 years or older.12 Indeed, per miles traveled, a 75 year old female has a greater risk of being involved in a fatal crash than a 16 year old male. The “U-shaped” nature of the fatality rates is not evident if the rates are based on population, rather than on distance traveled, since older drivers tend to drive much less often than their younger counterparts.12

Another analysis of FARS data from 1975 to 1990 suggests that driver fatality rates for middle-aged or elderly drivers at a given age are lower for more recently born birth cohorts.13 The reasons for these differences among birth cohorts are unknown. And, it remains to be seen how much safer older drivers will be over the next several years as the elderly population continues to increase in the U.S. It is also unknown at this time if there is a similar trend for the newest generations of drivers.

- **Driver Experience**

Inexperience or lack of skill at driving could have confounded the relationships seen between fatal crash risks and young age groups. Cooper et al. in 1995 examined the crash risks for novice Canadian drivers from a wide age range. Beginners from age 16 to 55 years had higher crash rates, and were more often found culpable for their crashes, compared to more experienced drivers of similar age.14 The possibility of confounders for the relationship between late age of licensure and crash risk was not addressed in the study. However, it may be that age is to some extent a surrogate for driving experience.
• **Gender**

Gender is another factor that is strongly related to the risk of crashes and crash deaths. Crash and fatality rates per capita are higher for males.\textsuperscript{2} However, when rates are based on 100 million VMT, females tend to have a higher incidence of injuries and police reported crashes. Per miles traveled, males still have a 55% greater risk of fatal crashes, whereas females have a 26% greater risk of crashes yielding injuries, and a 16% greater overall risk of crashes.\textsuperscript{12} The fewer miles traveled by, and, consequently, less driving experience of, females may account for this discrepancy in injuries and crashes.\textsuperscript{12}

When duration of time before a crash occurs is considered as a measure of risk, decreased risk is associated in both sexes with marriage and higher income; in males with more miles of driving experience; and, in females with more years of driving experience. Shorter durations to crashes were associated with a history of moving violations in males, and a history of previous crashes in females.\textsuperscript{15}

The causes of these gender differences, especially in fatalities, are elusive. But, male and female drivers may appreciate driving risks differently. DeJoy, in 1992, administered a driving risk questionnaire to young male and young female drivers from a college population. He found that males had more optimistic views of their own driving skills, and perceived certain dangerous driving conditions as less risky.\textsuperscript{16} Males may thus have a tendency to place themselves in high risk driving situations.
• **Ethnicity**

There are striking differences in motor vehicle-related fatality rates among ethnic groups. The death rate, per 100,000 population, is 42 for Native Americans; 20 for Whites; 17 for Blacks; and 11 for Asians.\(^{17}\) There are no known studies that explore the reasons behind these differences.

• **Alcohol Intoxication**

Alcohol intoxication is related to automobile crashes and deaths. This is believed to be a factor in 50% of all fatal crashes and 60% of all fatal single-vehicle crashes.\(^2, 11\) In non-fatal crashes, the frequency of alcohol intoxication correlates with the severity of the crash: 5% of drivers in property damage-only crashes have blood alcohol levels equal to or greater than 0.10%, compared to 9-13% of drivers in injury-producing crashes. Alcohol can impair driving skills and judgment, and may decrease tissue tolerance to the effects of trauma.\(^{11}\) Over the past decade, the proportion of drivers involved in fatal crashes who were intoxicated has decreased by about 21%.\(^3\)

• **Attitudes and Psychological Factors**

It is reasonable to expect that driving behavior is influenced by personal attitudes about driving safety and risk. However, a Norwegian study on driving attitudes found no relationship between unsafe attitudes and actual behavior. In this study, 15,000 licensed Norwegian drivers were given the same questionnaire about driving safety two years apart. The researcher found that drivers who had “correct” attitudes towards driving safety had fewer accidents per mile traveled than those with “incorrect” attitudes. How-
ever, when adjusted for age, the difference in accident risk was not apparent. He concluded that increased age and driving experience were more important for decreased accident risk, than were attitudes toward driving safety.\textsuperscript{18} It is unclear if these findings—a discordance between beliefs and behaviors over the short-term—is generalizable to other nations or cultures.

An interesting case control study on Australian army conscripts from the Viet Nam war era was performed in 1990. The researcher studied the presence of certain psychological and sociological factors in those who died from automobile crashes. He found that soldiers who died from crashes had higher odds of having lower army IQ scores, poorer educational levels, lower pre-service occupational status, a past history of juvenile infractions, and a history of going AWOL while on duty.\textsuperscript{19}

- **Speed Variability and Adaptation**

  On a roadway, increased variation in speed among vehicles, or decreased uniformity of traffic flow, may increase the risk of crashes. Higher speed limits on a particular highway may worsen speed variability, and, hence, increase the risk of crashes.\textsuperscript{2}

  As highway speed limits increase, average speeds on the non-Interstate, secondary roads may increase as well. Drivers may “adapt” or become accustomed to faster driving on highways, and subsequently, may drive faster on secondary roads that are posted with lower limits.\textsuperscript{2, 4} The effects of changes in highway speed limits may thus spill over, and be felt beyond the major highways into the remainder of a state’s roadways.
• Environmental Factors

• Location

The location of driving is strongly related to the risk of automobile crashes. The risk of death is much higher in rural areas, compared to urban areas.\textsuperscript{2, 17} Muelleman et al., in 1993, studied death certificate data for Nebraska from a five year period. The researchers found that the age-adjusted death rate from automobile crashes was 93\% higher in counties with less than 10,000 people, than in more populated areas.\textsuperscript{20} In 1996, Muelleman et al. studied FARS data for four different population density areas in four states. They found that occupant fatality rates were inversely related to population density. Fatal crashes in the less populated areas tended to involve more trucks, more frequent alcohol use, non-collision crashes, crashes on gravel surfaces, more frequent occupant ejection, and delayed medical care.\textsuperscript{21}

• Accessibility of Trauma Care

Delayed access to, or decreased availability of, trauma care services has been offered as an explanation for the increased fatality rates in rural areas. Maio et al. studied crash-related deaths in rural and non-rural areas in Michigan. They found that rural crashes tended to involve a greater level of vehicle damage, a higher rate of unbelted drivers, and more drivers aged 50 years or more. They concluded it was difficult to isolate medical resources as a factor; but, they state that about half of rural crash deaths may be accounted for by crash characteristics and older age.\textsuperscript{22} Chen et al. in 1995 studied rural and urban area fatalities in Michigan. They examined the severity of traumatic injuries using stan-
standard indexes or trauma scores, and calculated "preventable death rates." They concluded that fatally injured persons in rural areas sustained worse levels of trauma, and that ultimately the quality or quantity of rural medical care did not affect the outcome.23

- Agent Factors

- Engineering and Technology

Robertson, in 1996, analyzed crash data from 1975 to 1991 using regression analysis. He concluded that increased crashworthiness of cars contributed to lower crash death rates during this period.24

Usage of safety belts and airbags reduces the risk of injury or death from automobile crashes.2 In 1996, the U.S. Department of Transportation estimated that 10,414 lives were saved by seat belts, 686 lives were saved by air bags, and 365 lives were saved by child car seats. Since 1982, seat belts saved an estimated 85,396 lives.3

Automobile Crash Analyses

Automobile crashes are rather complex phenomena. Many factors may come into play during a single crash. Some factors may be more important in certain locations, or at certain times. And, some factors, such as road geometry or weather conditions,25, 26 may change in importance from day to day, or from hour to hour. Of the factors associated with automobile crashes, perhaps only age, gender, and ethnicity are immutable. Thus, examining specific factors may be difficult.
In the literature, several techniques for studying automobile crashes have been discussed and debated. On the whole, these study methods involve various linear regression, modeling, or correlational techniques,\textsuperscript{26-28} rather than the more traditional epidemiologic analytic designs.

Even the methods for measuring fatality rates are controversial. As with most causes of death, automobile crash fatality rates are often compared on a per capita basis. If different groups have significantly different proportions of automobile drivers or passengers, however, comparisons can be misleading. Rates based on licensed drivers may be more meaningful. However, comparisons could be misleading, if different groups of licensed drivers drove significantly different amounts, and hence, were exposed to road hazards differentially. The method of induced exposure attempts to account for differing amounts of driving and, hence, exposure. Groups are compared on the basis of the proportion of their drivers held responsible for causing a two-car crash. A higher proportion indicates higher risk.\textsuperscript{12} However, determination of culpability can be a subjective decision on the part of law enforcement authorities; and, the method does not address the issue of shared responsibility for a crash. Another method of comparison is based on vehicle miles traveled. However, calculation of mileage for specific groups or segments of drivers may be difficult to perform.\textsuperscript{12} It may be extremely difficult or impossible to determine individual miles traveled.
Increased Highway Speed Limits

In late 1973, certain Middle Eastern countries imposed an oil embargo against the U.S. for supporting Israel during the Yom Kippur war. The following year, Congress established a National Maximum Speed Limit (NMSL) of 55 mph, to conserve national petroleum supplies. The NMSL was raised to 65 mph in 1987. It was rescinded altogether in 1995. Several states now allow highway speed limits much higher than the previous level of 65 mph. One state, Montana, permits motorists on public highways during the day to travel as fast as they deem prudent, based on road conditions.

New Highway Speed Limits and Mortality

Since the NMSL was raised in 1987 several studies have suggested that automobile crash fatality rates have increased. By and large, they have involved linear regression, correlational, or descriptive designs.

Baum et al. in 1989 examined fatality rates in the 38 states that raised speed limits to 65 mph in 1987. They concluded that fatality rates were higher after the change. Also, they found that the odds of death were higher on rural Interstates compared to other rural roads, and compared to all other roads.29

Gallaher et al. in 1989 studied the automobile fatality rate in New Mexico, after that state’s rural Interstate speed limit was increased in 1987. They used linear regression methods and data from fatality trends from the previous five years to predict the rate of fatal crashes, had the speed limit not changed. They concluded that fatality rates increased with the 65 mph speed limit.30
Garber et al. in 1990 studied FARS data for each state, using multiple regression analysis and time series techniques. They concluded that the 65 mph highway limit had disparate effects, depending upon the state. They concluded that fatalities increased in some states, decreased in others, and stayed the same in the remainder. Overall, they concluded that the median increase in fatalities on rural Interstate highways was 15%.4

Wagenaar et al. in 1990 examined fatalities and injuries in Michigan on highways that had 65 mph speed limits, compared to highways with lower limits. Their multiple time series study concluded that fatalities increased by 19.2%; serious injuries, by 39.8%; and moderate injuries, by 19.2%.31

Rock in 1995 examined automobile crashes in Illinois on highways with 65 mph and 55 mph limits. He concluded that higher speed limits increased the rate of crashes, injuries, and deaths.32

However, Lave et al. in 1994 used regression analysis to study fatalities in the states with 65 mph speed limits. They concluded that overall statewide fatality rates based on mileage decreased with the higher limit. They argued that higher speed limits may allow state highway patrol departments to divert resources from speed limit enforcement to other intramural activities. This change in emphasis, they claimed, may thus promote overall or system-wide road safety.5
METHODS AND PROCEDURES

Overview

This study used a case-control design. Case and control subjects were identified from two separate, publicly available computerized mortality databases. The coverage of these databases overlapped during 1991 to 1993; hence, these years were chosen for the study period. Commercial statistical, spreadsheet, and database management programs were used to extract, manipulate, and analyze the data. Cases were divided into three groups, based on how the motor vehicle accident occurred. Four control groups were used, each group representing a different cause of death.

Case Subjects

The cases were obtained from a Fatal Accident Reporting System datafile. The FARS system contains detailed descriptions of each fatal motor vehicle accident in the US by year. To be included in the system, an accident must have involved a motor vehicle on a public roadway, with the death or deaths occurring within one month. Each accident is described in four broad data fields: an overall description of the accident; descriptions of the motor vehicles involved in the accident; descriptions of the drivers; and descriptions of the injured persons. Each broad field has several sub-fields, permitting a large amount of information to be recorded for each accident.

The FARS datafiles used for the study were contained in the Traffic Safety CD-ROM 1996 (Bureau of Transportation Statistics, US Department of Transportation). All of a spe-
pecific year's accidents are contained in one large ASCII text flat file. Each line of text contains 106 spaces, and represents a single record for either the accident level, vehicle level, driver level, or person level data fields. The information for each sub-field is coded with letters, numbers, or both, and entered within a specific location on its line.

Records for the accident level fields contain coded data in all the 106 spaces. Records for the remaining fields contain asterisks or blank spaces in certain locations on the line. Thus, by examining certain spaces for these symbols or for coded data, it is possible to discern the type of data field represented by each line of text. Each accident is assigned a state and case number, which is included in all of its corresponding records. Thus, it is possible to link together all the appropriate records for an accident, even though the datafile is not truly organized or sub-divided by each accident.

The Minitab Version 11 for Windows 95 statistical program was used to import the datafile for each study year. Using the record description documents included on the FARS CD-ROM to ascertain the locations of the asterisks or blanks characteristic of each data field, it was possible with the software to segregate the records according to the accident and person level fields. Microsoft Access 97 was used to link an accident level record with its appropriate person level record.

Using the code book supplied on the CD-ROM, fatally injured drivers were identified and segregated according to the first harmful event. The first harmful event is the first injury- or property damage-producing event in an accident, as determined by the law enforce-
ment authorities. Table 1 presents the three general categories of accidents used in the study, and the specific events included in each.

Drivers whose ages were unknown, not specified, or less than 15 years were excluded. Minitab was used to obtain simple random samples from the resulting eligible populations. The final study populations were 2000, 4000, and 4000 for the non-collision, collision with motor vehicles in transit, and collision with stationary objects groups. The samples were stratified according to ten year age intervals, starting at 15 years and ending at $\leq 75$ years, and according to sex. Federal Information Processing System (FIPS) codes were used to further separate the strata into the exposed (high speed limit state) and non-exposed (slow speed limit state) groups for the data analysis.

The Multiple Cause of Death Files also contain information on persons dying from motor vehicle accidents. However, information on the person type (for example, driver, passenger, or pedestrian) was frequently not specified. Thus, this database was not useful as a source of case subjects.

**Control Subjects**

Decedents selected as controls were obtained from the Multiple Cause of Death Files CD-ROMs (National Center for Health Statistics, US Department of Health and Human Services) for 1991, 1992, and 1993. The SETS Version 1.22a database program, included on the CD-ROMs, was used to extract the death records according to the underlying cause of death. Persons dying from unintentional poisoning by solids or liquids (ICD-9 Codes E850 to E859, and E860 to E866); non-Hodgkins lymphoma (ICD-9 Code 202.8); accidental non-
boating drowning or submersion (ICD-9 Code E910); and diabetes mellitus (ICD-9 Code 250) were selected as controls.

The control groups datafiles were imported into Minitab. Control subjects whose ages were unknown, not specified, or less than 15 years were excluded. Simple random samples were obtained from the resulting eligible populations. The final study populations were 4000, 4000, 2000, and 8000 for the poisoning, non-Hodgkins lymphoma, drowning, and diabetes mellitus groups, respectively. As with the cases, the control samples were stratified according age and sex. FIPS codes were used to further separate the strata into the exposed and non-exposed groups for the data analysis.

**Exposure Factor**

Between 1991 and 1993, nine states had maximum speed limits of 55 mph: Connecticut, Delaware, the District of Columbia, Hawaii, Maryland, New Jersey, New York, Pennsylvania, and Rhode Island. The remaining states had maximum speed limits of 65 mph, with the exception of Alaska, which had a maximum limit of 60 mph during 1991 and 1992.

The latter group was considered the high speed states, or the exposed group. The former group was considered the slow speed states, or the non-exposed group. A subject was considered exposed or non-exposed, based on the state speed group in which his death occurred.
Data Analysis

For each year during the study period, 1991 to 1993, each case and control group was divided according to exposure or non-exposure. Each of the three case groups was compared with each of the four control groups of the same year, resulting in a total of 12 separate comparisons per study year. Also, all case and control pairs were broken down into two gender and seven age strata.

The stratified data were entered into Epi Info Version 6 for DOS to calculate the crude odds ratios, Mantel-Haenszel weighted odds ratios, Cornfield 95% confidence limits for the weighted odds ratios, and p-values. Since the case and control groups differ with respect to age and sex distributions, the Mantel-Haenszel technique was used to help control for these dissimilarities.
RESULTS

Sample Sizes of the Case and Control Groups

The sample sizes for the case groups are presented in Table 2. The FARS datafile yielded three sets of fatally injured drivers, based on the first harmful event of the accident. These case groups were deaths from non-collision accidents; collisions with motor vehicles in transit; and collisions with stationary objects. During the three year study period, non-collision deaths ranged from 2500 to 2800 per year; collision with motor vehicles in transit deaths, from 10900 to 11600 per year; and collision with stationary object deaths, from 8500 to 9200 per year. Cases for which the age was unknown, not specified, or less than 15 years were excluded from the study. This reduced the pools of cases by less than one percent. The final randomly selected study samples comprised 35% to 81% of their respective eligible populations.

The sample sizes for the control groups are presented in Table 3. The Multiple Cause of Death File yielded four sets of control groups, based on the underlying cause of death. The control groups were deaths from unintentional poisoning from solids or liquids (ICD-9 Codes E850 to E859, and E860 to E866); non-Hodgkins lymphoma (ICD-9 Code 202.8); accidental non-boating drowning and submersion (ICD-9 Code E910); and diabetes mellitus (ICD-9 Code 250). Deaths from poisoning from solids or liquids ranged from 5700 to 7900 per year; deaths from non-Hodgkins lymphoma, from 17500 to 19400 per year; deaths from drowning, from 3600 to 4000 per year; and deaths from diabetes mellitus, from 49000 to 54000 per year. As with the case groups, control subjects for which the age was unknown,
not specified, or less than 15 years were excluded. The reduction in the pools of controls was variable: about 30% for the drowning group, and 1% or less for the others. The final randomly selected study samples comprised 20% to 80% of their respective eligible populations.

**Characteristics of the Case and Control Groups**

The age and sex characteristics of the case groups are presented in Table 4. The median ages of the non-collision and the collision with stationary objects groups were similar: 30 to 32 years. Interestingly, the median ages of the collision with motor vehicles in transit groups were consistently higher, at 38 years. The age distributions for all case groups were skewed to the right. For both the non-collision and the collision with stationary objects groups, males predominated by a 4:1 ratio. The ratio of males to females for the collision with motor vehicles in transit group was about 2.3:1.

The age and sex characteristics of the control groups are presented in Table 5. The median ages for the poisoning, non-Hodgkins lymphoma, drowning, and diabetes mellitus groups were, respectively, 37-38, 71-73, 33-35, and 73. The two accidental death groups, poisoning and drowning, had age distributions that were skewed to the right. The other two control groups had age distributions skewed to the left. For the poisoning and drowning groups, males predominated by 3:1 and more than 5:1, respectively. The sex distribution for non-Hodgkins lymphoma was about equal. Females predominated slightly, at a ratio of 1.3:1 for the diabetes mellitus group.

Tables 6 to 11 present the age group and sex breakdowns of both the case and control groups for the contingency tables and odds ratio calculations.
Odds Ratios for Non-Collision Driver Death

The odds ratios for non-collision driver deaths are presented in Table 12. Over all control groups and the three study years, the adjusted odds ratios for driver death occurring in the exposed (high speed limit) states are elevated. The range is from 2.80 to 7.10. The lower 95% confidence limit ranged from 2.19 to 5.78. P-values were all highly significant.

Odds Ratios for Collision with Motor Vehicles in Transit Driver Death

The odds ratios for collision with motor vehicles in transit driver deaths are presented in Table 13. The adjusted odds ratios for driver death occurring in the exposed states are elevated for all control groups and the three study years. For the poisoning, non-Hodgkins lymphoma, and diabetes mellitus control groups, the adjusted odds ratios ranged from 1.50 to 2.36. The lower 95% confidence limit using these groups ranged from 1.29 to 2.06. The corresponding p-values were highly significant. However, the odds ratios utilizing the drowning control groups did not reach statistical significance at the p = 0.05 level.

Odds Ratios for Collision with Stationary Objects Driver Death

The odds ratios for collision with stationary objects driver deaths are presented in Table 14. The adjusted odds ratios for driver death occurring in the exposed states are significantly elevated over all study years for the poisoning and non-Hodgkins lymphoma control groups. For these groups, the adjusted odds ratios ranged from 1.31 to 1.91. The corresponding lower 95% confidence limits ranged from 1.12 to 1.69. The corresponding p-values were all highly significant.
All adjusted odds ratios utilizing the drowning groups, however, were not elevated. For the year 1992, the adjusted odds ratio of 0.85 carried a p-value of about 0.04. The corresponding 95% confidence limit ranged from 0.73 to 0.99. The remaining odds ratios were not statistically significant at the p = 0.05 level.

In the diabetes mellitus control group, the adjusted odds ratios were significantly elevated for the years, 1991 and 1992. The corresponding lower 95% confidence limits were 1.30 and 1.41. For 1993, the adjusted odds ratio was slightly elevated at 1.07, but did not reach statistical significance.

**Odds Ratios for Each Stratum**

Crude odds ratios for each age and sex stratum are presented in Tables 15 to 20. The stratum-specific odds ratios tended to vary widely. There was no discernible pattern with respect to age or year.
DISCUSSION AND CONCLUSION

Strength of Association

The main overall findings were increased risks of driver deaths in the states with maximum highway speed limits of 65 mph.

Adjusted odds ratios were consistently high, and highly statistically significant, over all study years, and with all control groups for non-collision accidents.

For driver deaths involving collisions with other motor vehicles in transit, the adjusted odds ratios were moderately strong and statistically significant with three of the four control groups. The elevated odds ratios for the remaining control group were not significant.

Driver deaths in collisions with stationary objects on the roadway appeared to be associated with the high speed states when compared to the poisoning and non-Hodgkins lymphoma controls. There may have been a slight negative association when compared to the drowning controls. For the diabetes mellitus controls, the association with the high speed states was significant, except for one year.

Significance of the Findings

Although still controversial, most studies have concluded that raising the NMSL to 65 mph in 1987 raised the risk of motor vehicle crash death. Historically, crash death rates decreased during the era of the national 55 mph limit, and increased when the NMSL was raised. Faster driving decreases reaction times, and increases stopping distances. Kinetic
energy, which is dissipated through the motor vehicle structure, outside objects, and human tissues during a crash, increases as the square of the velocity of the vehicle. The phenomenon of speed adaptation suggests that increases in highway speeds will be felt over much of a state’s roadway system. This study is consistent with most of the literature. However, this is the first to utilize the case-control method.

Lave, in 1994, proposed that the higher speed limit could help decrease overall crash deaths, by allowing law enforcement authorities to shift resources and attention from speed limit control to other intramural safety activities. This assertion is interesting and provocative. However, if such were the case, the association of driver deaths with the high speed states should have been negative.\(^5\)

**Alternative Explanations**

Alternative explanations for these findings are possible. First, it is not likely that chance produced the high odds ratios, since the p-values tended to be rather small.

Second, certain regional or geographical factors were not considered, but may have biased the observed associations. Most of the slow speed states are clustered in the northeast. The cooler regional climate could have reduced the frequency or duration of driving, thus suppressing the numbers of crash deaths. Likewise, people in cooler climates may engage in water sports less frequently, thus suppressing the number of drowning deaths. This may account for the lower odds ratios with the drowning control groups. Regional economic conditions could modulate the frequency of driving, or affect how drivers maintain or repair their vehicles. Differences in the distribution of vehicle types (cars, trucks, sport vehicles, and
motorcycles) and their safety features could affect the risk of dying in a crash. Geographic differences in drunk driving and seat belt usage rates could also affect the risk of crash death. The quality of driving education programs, local road conditions, law enforcement activities, or emergency medical care could have varied between the two regions. The influence of these possible factors is unknown.

Third, regional attitudes and behaviors with respect to road safety could have confounded the observed associations. A “safety-minded” region may have safer drivers, maintain its roads better, and promote safer driving habits and regulations. And, it may be in no hurry to increase its local speed limits. Interestingly, while many states immediately increased their speed limits when Congress raised the NMSL to 65 mph in 1987, the slow speed states opted to hold back for several years. It may be difficult to measure or control for these possible cultural influences.

**Methodological Issues**

Ideally, a control group in a case-control study should be comparable to the source population of the case subjects. Since there is a correlation between state motor vehicle and other unintentional injury death rates, there may be factors common among those who die in accidents. Hence, unintentional poisoning and accidental drowning deaths may be appropriate sources for control groups. Also, since the physical requirements for motor vehicle operation are minimal, controls from the general population may be considered. Non-Hodgkins lymphoma and diabetes mellitus are two disparate but common general medical conditions that may also be appropriate as sources for controls.

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Motor vehicle deaths are unique in that the age distribution is strongly skewed, with a preponderance of victims in the younger age groups. This is in contrast to most other diseases, which cause death in the middle-aged or elderly. The age distributions of the cases and controls (especially the non-Hodgkins lymphoma and diabetes mellitus controls) were dissimilar. The sex distributions were likewise dissimilar. However, stratifying by age and sex, and using the Mantel-Haenszel weighted odds ratio technique should help to mitigate these differences. Since the crude and adjusted odds ratios were on the whole comparable, these differences were likely not significant in this study.

Two independent datasets were used. Both sets yielded information on age, sex, and the state in which the death or accident occurred. However, it was not possible to compare the case and control groups on other variables. FARS contains information drivers' licensing statuses and traffic law conviction histories. This is not contained in the Multiple Cause of Death File. However, the Multiple Cause of Death File contains information on ethnicity and educational level, which is not found in FARS. Neither dataset contains information regarding history of alcohol or drug use, seat belt usage habits, socio-economic status, or frequency of driving. Hence, it was not possible to compare the case and control groups beyond a few demographic variables.

Conclusion

Using a case-control design and extant databases, this study shows an association between driver deaths and high maximum state speed limits, during 1991 to 1993. The association is strongest and most consistent with deaths involving non-collision-type accidents.
Some factors may have influenced these observed associations, however. Legislation concerning speed limits should carefully consider the potential risks of high speed driving, as well as its benefits.

Considering the ubiquity of driving in our society, and the magnitude of the public health problem of motor vehicle crashes, further study is warranted. Intervention trials in which state or local speed limits are lowered may not be practical or politically possible. Prospective or retrospective cohort studies may be possible. Computerized state driver license databases may allow subjects to be identified and tracked longitudinally. Also, military personnel, with their frequent moves and transfers within the US, may be a convenient source of cohorts. However, since motor vehicle fatality rates are low in absolute terms, very large numbers of subjects may be needed over long study periods. Also, coordinating a longitudinal study with several state motor vehicle bureaus will probably present significant logistical challenges. Since motor vehicle fatality datasets are now readily available and accessible by desktop computers, further case-control studies may be performed relatively quickly and cheaply. Basic research on driver behavior, psychology, or driving skills and performance may also help shed light on this public health problem.
Table 1. Categories of Accidents Used for the Three Case Groups

**Non-Collision Group**
Included the following first harmful events:

- Overtum
- Immersion
- Other non-collision
- Irregular pavement

**Collision with Motor Vehicles in Transit Group**
Included the following first harmful events:

- Striking a vehicle in transit on the same roadway
- Leaving a roadway and striking a vehicle in transit on another roadway

**Collision with Stationary Objects Group**
Included the following first harmful events:

<table>
<thead>
<tr>
<th>Parked motor vehicle</th>
<th>Other post/ pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>Culvert</td>
</tr>
<tr>
<td>Other non-fixed object</td>
<td>Ditch</td>
</tr>
<tr>
<td>Building</td>
<td>Embankment-earth</td>
</tr>
<tr>
<td>Impact attenuator</td>
<td>Embankment-rock</td>
</tr>
<tr>
<td>Bridge pier</td>
<td>Embankment-unknown</td>
</tr>
<tr>
<td>Bridge parapet</td>
<td>Fence</td>
</tr>
<tr>
<td>Bridge rail</td>
<td>Wall</td>
</tr>
<tr>
<td>Guardrail</td>
<td>Fire hydrant</td>
</tr>
<tr>
<td>Concrete barrier</td>
<td>Shrubbery</td>
</tr>
<tr>
<td>Other L-barrier</td>
<td>Tree</td>
</tr>
<tr>
<td>Highway sign post</td>
<td>Other fixed object</td>
</tr>
<tr>
<td>Overhead sign</td>
<td>Traffic equipment</td>
</tr>
<tr>
<td>Light support</td>
<td>Traffic sign support</td>
</tr>
<tr>
<td>Utility pole</td>
<td></td>
</tr>
</tbody>
</table>

**First Harmful Events Not Used in the Study**

<table>
<thead>
<tr>
<th>Fire/ explosion</th>
<th>Striking a pedalcycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas inhalation</td>
<td>Striking a train</td>
</tr>
<tr>
<td>Falling from a motor vehicle</td>
<td>Striking an animal</td>
</tr>
<tr>
<td>Injured inside a motor vehicle</td>
<td>Other non-motor vehicle event</td>
</tr>
<tr>
<td>Striking a pedestrian</td>
<td>Hit by a thrown or falling object</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Non-Collision Deaths</td>
<td></td>
</tr>
<tr>
<td>Raw N</td>
<td>2550</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
<td>2533</td>
</tr>
<tr>
<td>% of Raw N</td>
<td>99.3%</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
<td>79.0%</td>
</tr>
<tr>
<td>Collision with Motor</td>
<td></td>
</tr>
<tr>
<td>Vehicles in Transit Deaths</td>
<td></td>
</tr>
<tr>
<td>Raw N</td>
<td>11576</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
<td>11533</td>
</tr>
<tr>
<td>% of Raw N</td>
<td>99.6%</td>
</tr>
<tr>
<td>Study N</td>
<td>4000</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
<td>34.7%</td>
</tr>
<tr>
<td>Collision with Stationary Objects Deaths</td>
<td></td>
</tr>
<tr>
<td>Raw N</td>
<td>8500</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
<td>8473</td>
</tr>
<tr>
<td>% of Raw N</td>
<td>99.7%</td>
</tr>
<tr>
<td>Study N</td>
<td>4000</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
<td>47.2%</td>
</tr>
</tbody>
</table>

*Size after removing subjects <15 years old, or with unknown age.*
<table>
<thead>
<tr>
<th>Table 3. Sample Sizes of the Control Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisoning by Solids or Liquids Deaths</td>
</tr>
<tr>
<td>Raw N</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
</tr>
<tr>
<td>% of Raw N</td>
</tr>
<tr>
<td>Study N</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
</tr>
<tr>
<td>Non-Hodgkins Lymphoma Deaths</td>
</tr>
<tr>
<td>Raw N</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
</tr>
<tr>
<td>% of Raw N</td>
</tr>
<tr>
<td>Study N</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
</tr>
<tr>
<td>Drowning (Non-Boating) Deaths</td>
</tr>
<tr>
<td>Raw N</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
</tr>
<tr>
<td>% of Raw N</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
</tr>
<tr>
<td>Diabetes Mellitus Deaths</td>
</tr>
<tr>
<td>Raw N</td>
</tr>
<tr>
<td>Eligible Sample N*</td>
</tr>
<tr>
<td>% of Raw N</td>
</tr>
<tr>
<td>Study N</td>
</tr>
<tr>
<td>% of Eligible Sample N</td>
</tr>
</tbody>
</table>

*Size after removing subjects <15 years old, or with unknown age.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-Collision Deaths</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Range</td>
<td>15-99</td>
<td>15-99</td>
<td>15-87</td>
</tr>
<tr>
<td>Median Age</td>
<td>32</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Mean Age ± SD</td>
<td>34.9 ± 15.4</td>
<td>34.6 ± 15.2</td>
<td>33.9 ± 14.6</td>
</tr>
<tr>
<td>Males</td>
<td>1614 (80.7%)</td>
<td>1548 (77.4%)</td>
<td>1603 (80.2%)</td>
</tr>
<tr>
<td>Females</td>
<td>386 (19.3%)</td>
<td>452 (22.6%)</td>
<td>397 (19.8%)</td>
</tr>
<tr>
<td><strong>Collision with Motor Vehicles in Transit Deaths</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Age Range</td>
<td>15-99</td>
<td>15-99</td>
<td>15-93</td>
</tr>
<tr>
<td>Median Age</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
<tr>
<td>Mean Age ± SD</td>
<td>43.3 ± 20.7</td>
<td>43.3 ± 20.5</td>
<td>43.1 ± 20.6</td>
</tr>
<tr>
<td>Males</td>
<td>2759 (69.0%)</td>
<td>2807 (70.2%)</td>
<td>2784 (69.6%)</td>
</tr>
<tr>
<td>Females</td>
<td>1241 (31.0%)</td>
<td>1193 (29.8%)</td>
<td>1216 (30.4%)</td>
</tr>
<tr>
<td><strong>Collision with Stationary Objects Deaths</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Median Age</td>
<td>32</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Mean Age ± SD</td>
<td>36.7 ± 17.5</td>
<td>36.5 ± 17.6</td>
<td>35.7 ± 17.1</td>
</tr>
<tr>
<td>Males</td>
<td>3215 (80.4%)</td>
<td>3244 (81.1%)</td>
<td>3269 (81.7%)</td>
</tr>
<tr>
<td>Females</td>
<td>785 (19.6%)</td>
<td>756 (18.9%)</td>
<td>731 (18.3%)</td>
</tr>
<tr>
<td>Table 5. Age and Sex Characteristics of the Controls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Underlying Cause of Death</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Poisoning by Solids or Liquids Deaths</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Age Range</td>
<td>15-103</td>
<td>15-120</td>
<td>15-103</td>
</tr>
<tr>
<td>Median Age</td>
<td>38</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td>Mean Age ± SD</td>
<td>40.4 ± 13.2</td>
<td>40.7 ± 14.7</td>
<td>41.0 ± 15.8</td>
</tr>
<tr>
<td>Males</td>
<td>3089 (77.2%)</td>
<td>3024 (75.6%)</td>
<td>2890 (72.2%)</td>
</tr>
<tr>
<td>Females</td>
<td>911 (22.8%)</td>
<td>976 (24.4%)</td>
<td>1110 (27.8%)</td>
</tr>
<tr>
<td><strong>Non-Hodgkins Lymphoma Deaths</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>4000</td>
<td>4000</td>
<td>4000</td>
</tr>
<tr>
<td>Age Range</td>
<td>15-106</td>
<td>16-106</td>
<td>15-104</td>
</tr>
<tr>
<td>Median Age</td>
<td>72</td>
<td>72</td>
<td>71</td>
</tr>
<tr>
<td>Mean Age ± SD</td>
<td>68.8 ± 14.8</td>
<td>69.1 ± 14.9</td>
<td>68.4 ± 15.0</td>
</tr>
<tr>
<td>Males</td>
<td>2068 (51.7%)</td>
<td>2079 (52.0%)</td>
<td>2126 (53.2%)</td>
</tr>
<tr>
<td>Females</td>
<td>1932 (48.3%)</td>
<td>1921 (48.0%)</td>
<td>1874 (46.9%)</td>
</tr>
<tr>
<td><strong>Drowning (Non-Boating) Deaths</strong></td>
<td></td>
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| Non-Hodgkin's Lymphoma Controls, N = 4000                   |
| Males           |       |       |       |       |       |       |     |
| Exposed         | 14    | 51    | 102   | 138   | 272   | 459   | 569 |
| Non-Exposed     | 2     | 18    | 44    | 53    | 74    | 127   | 156 |
| By Sex Only     |       |       |       |       |       |       | 1605|
| Females         |       |       |       |       |       |       |     |
| Exposed         | 6     | 23    | 44    | 80    | 171   | 424   | 754 |
| Non-Exposed     | 6     | 9     | 20    | 22    | 59    | 118   | 185 |
| By Age Only     |       |       |       |       |       |       | 419 |

| Drowning (Non-Boating) Controls, N = 2000                   |
| Males           |       |       |       |       |       |       |     |
| Exposed         | 432   | 315   | 260   | 153   | 101   | 88    | 90  |
| Non-Exposed     | 48    | 55    | 57    | 20    | 19    | 21    | 12  |
| By Sex Only     |       |       |       |       |       |       | 1439|
| Females         |       |       |       |       |       |       |     |
| Exposed         | 46    | 46    | 45    | 22    | 28    | 25    | 61  |
| Non-Exposed     | 5     | 11    | 5     | 2     | 7     | 12    | 14  |
| By Age Only     |       |       |       |       |       |       | 273 |

| Diabetes Mellitus Controls, N = 8000                        |
| Males           |       |       |       |       |       |       |     |
| Exposed         | 16    | 53    | 111   | 258   | 474   | 755   | 1052|
| Non-Exposed     | 3     | 16    | 45    | 52    | 115   | 205   | 300 |
| By Sex Only     |       |       |       |       |       |       | 2719|
| Females         |       |       |       |       |       |       |     |
| Exposed         | 7     | 27    | 86    | 161   | 462   | 935   | 1905|
| Non-Exposed     | 0     | 10    | 28    | 40    | 121   | 267   | 496 |
| By Age Only     |       |       |       |       |       |       | 3583|

| By Age Only     |       |       |       |       |       |       | 962 |

| By Age Only     |       |       |       |       |       |       | 2957|

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**Table 17. Collision with Motor Vehicles in Transit Death Odds Ratios for Males by Age Group, Control Group, and Year**
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REFERENCES


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VITA

Grover K. Yamane was born in Seattle, Washington, on 30 October 1959, the son of Tsuruyo O. Yamane and the late Jim H. Yamane. After completing Cleveland High School, Seattle, Washington, in 1977, he attended Yale University, New Haven, Connecticut. During the summer of 1980, he attended the University of Washington, Seattle, Washington, under a National Science Foundation Summer Undergraduate Research Fellowship in the Department of Medicinal Chemistry. In 1981, he graduated from Yale with a Bachelor of Arts degree in Chemistry, cum laude. He attended New York Medical College, Valhalla, New York, and received a Doctor of Medicine degree in 1985. He served an internship in General Surgery at the Buffalo General Hospital, Buffalo, New York, and then a residency in Family Practice at the Mid-Hudson Family Health Services Institute, Kingston, New York. He completed the residency in 1989, and was board-certified in Family Practice the same year. Since that time, he has been serving with the US Air Force as a family physician and flight surgeon. He currently holds the rank of Lieutenant Colonel. He married Jill Y. Marks of Harrisonburg, Virginia, in 1991. They have two sons, Maxwell and Miles.

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