An Analysis of USMC Accidental Deaths: 2007 Update

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ANALYSIS & SOLUTIONS

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Summary

Background

In 2003, CNA conducted a study that identified individual risk factors contributing to off-duty fatalities across the U.S. Marine Corps (USMC) [1]. Much has changed since 2003 in USMC lifestyles and driving practices. The USMC has been to war; the prevalence of motorcycle ownership has increased; and vehicle fatality rates have reached new highs.

As a result, the Director of the USMC Headquarters Safety Division asked CNA to refresh the earlier study and to explore how at-risk factors may have changed. The objective of this study is to determine, in an analytically sound manner, the variety of factors that explain motor-vehicle fatality rates. The hope is that this will aid in selecting and implementing tools and interventions to reduce deaths.

Tasking and study approach

We addressed the following tasks:

- *Build a data set.* We built a data set characterizing individual Marines and vehicle fatalities covering the time period from October 1998 through September 2007. Individual personnel records are the principal source of data, although we also incorporate additional information from safety records.
- *Perform statistical analysis.* We undertook a statistical analysis to estimate the risk of a vehicle-related fatality. In the analysis, we look at the relationship of various individual characteristics and career events to risk. We use an approach referred to as survival or hazard rate analysis [2, 3], a technique often used to evaluate the effectiveness of medical treatment. In addition, we provide a summary graphical analysis of the USMC fatality data, with com-

parisons against equivalent civilian data, and an exploration of changes that have occurred over this time period.

This study differs from our earlier work in a number of ways:

- We focus on motor-vehicle fatalities. The previous study addressed all off-duty deaths, considering motor-vehicle deaths secondarily.
- We look separately at motorcycle fatalities, as well as at overall vehicle fatalities. Motorcycle-related fatalities have been increasing and their risk profile seems to differ from that of other vehicle deaths.
- We look at differences in risk factors across geographical regions. We hope this will help indentify effective safety programs.
- We explore how risk factors have changed over the study period. This was a period of transition with wartime deployments and motorcycle ownership both seeming to have an increasing effect on fatality rates.

Summary of study findings

Our primary interest is in the factors that explain vehicle fatality rates. Some of our results are summarized as follows:

- *Early career.* A Marine's risk of death is more than twice as high during the second half of their first year in service as it is at other times. There is a period of low risk shortly after joining a new command. These findings have not changed.
- *Post deployment.* The period after returning from deployment is associated with substantial risk of fatality. The risk is particularly high in the interval 3 to 6 months following the return from deployment.
- *Occupational field.* Aviation mechanics and motor transport mechanics have high risks of a vehicle-related death. Infantry, artillery, personnel and administration, and aviation mechanics face the highest risk of motorcycle death, with their risk roughly double that facing most other Marines.

- *Location.* Marines at 29 Palms, Norfolk, and Camp Lejeune face the highest risk of automobile deaths.[1] The risk of motorcycle death is highest at Camp Pendleton.
- *Pay grade.* The E5 and E6 grades face the highest risk of a motorcycle fatality. Warrant officers face the highest risk of any vehicle fatality.
- *Enlistment waivers.* Individuals with an enlistment waiver for drug use have a 30 percent increase in risk of a vehicle fatality and a 50 percent higher risk of a motorcycle fatality as compared to those who enter without waivers. Individuals with felony waivers have a risk of motorcycle fatality more than four times higher than those with no waiver. These individuals account for a remarkable 7 percent of motorcycle deaths.
- *Demotions and promotions.* Individuals who were demoted 3 to 6 months earlier face a risk of motorcycle fatality more than three times higher than others. There is a very low likelihood of fatality for individuals in the 3 months following promotion.
- *Race and ethnicity.* In contrast to the previous study, we find no strong relationship between race or ethnicity and the risk of vehicle fatality. However, it is of note that no Blacks have been involved in fatal motorcycle accidents
- *Gender.* Females aged 19 or 20 have a surprisingly high risk of automobile fatality, higher than that of males. On the other hand, motorcycle fatalities have been exclusively male.
- *Time of year.* Spring and summer months are associated with more than a 50 percent increase in overall risk relative to the winter quarter. The risk of a motorcycle fatality is three times higher in the spring than in the winter.

The statistically significant results are illustrated in figure 1. The figure shows, separately, the risks for vehicle fatalities and motorcycle fatalities. A hazard ratio of greater than one indicates a risk above baseline. A value of less than one means lower risk.

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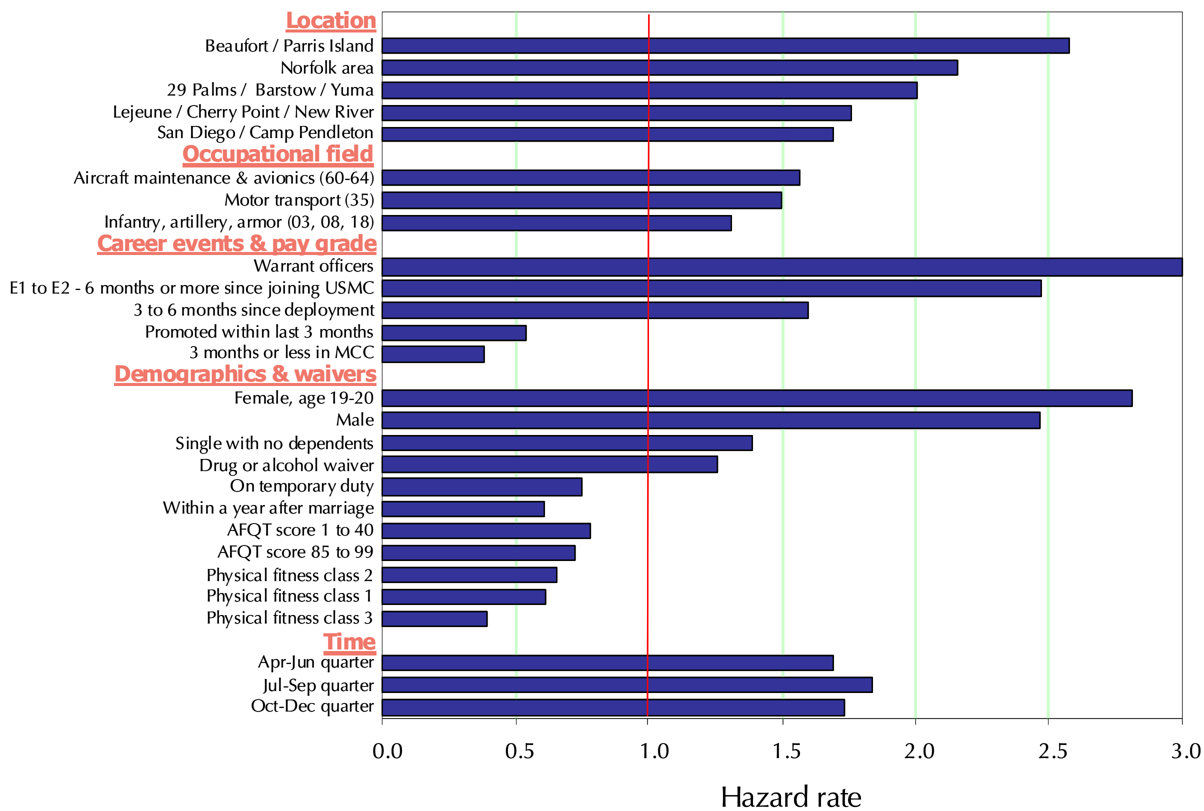
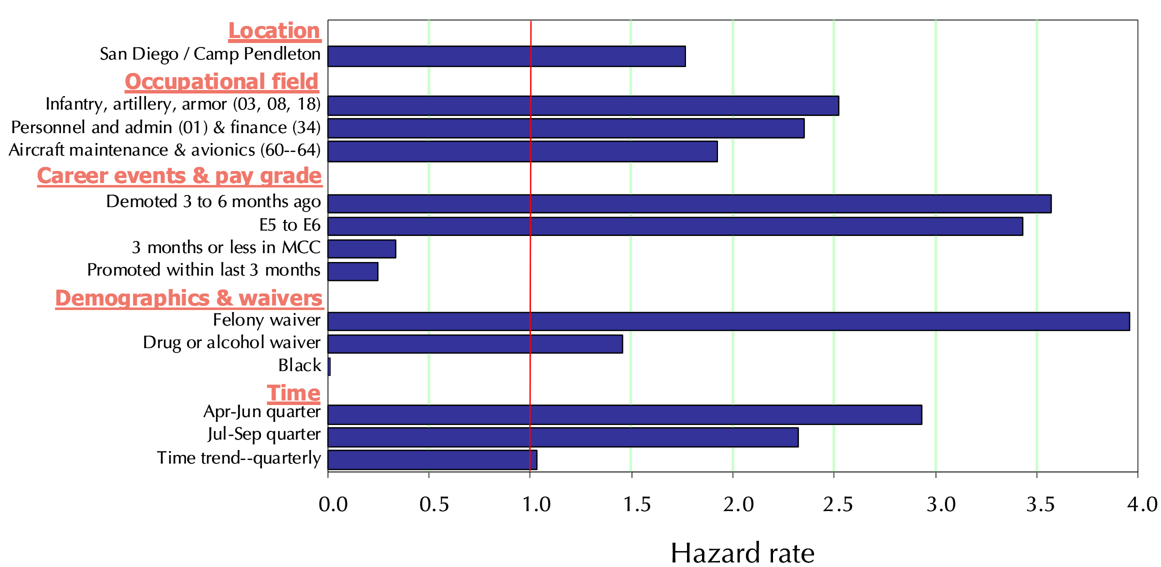
1. We also find inherently high risks for the Beaufort area, but fatality counts there are held down by the restrictive environment of recruit training.

Figure 1. Key risk factors for vehicle fatalities

All vehicles



Motorcycles



Some other findings are as follows:

- *Vehicle fatalities by time of day.* In looking at vehicle fatalities by time of day, the most striking feature of the data is the high death rate during the morning rush hours. The fatality rates in early morning hours are lower than we saw in the previous study, but still suggest that Marines are taking risks to make muster.

- *Comparison to civilian fatality rates.* In general, USMC automobile death rates are below those for civilians of equivalent age. The same is not true for motorcycles deaths. In 2006, the USMC motorcycle fatality rate was 70 percent higher than the equivalent civilian rate. Motorcycle fatality rates are especially high among Marines over the age of 25, individuals who should set an example for younger Marines.

- *Increasing motorcycle fatality rates.* There are some disturbing trends. Motorcycle fatality rates have been increasing at a rate of 13 percent a year, with the increase in deaths most pronounced in mid-level enlisted ranks (E4 to E6). The rate of increase in motorcycle deaths is also high for infantrymen.

- *Post-deployment effects.* With increased numbers of Marines returning from deployment, it is no surprise that more deaths would be observed in the post-deployment period than we saw in our earlier study. Still, the spike in the number of deaths 3 to 6 months after return from deployment merits attention.

Organization of this report

In the first section, we present an overview of USMC accidental death statistics, with some comparison to civilian rates. In the second section, we describe our statistical models and results. In the statistical analysis, we evaluate (1) risk factors for all vehicle-related deaths, (2) risk factors for motorcycle deaths, and (3) whether risk factors are changing over time.

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Overview of the data on USMC vehicle deaths

In this section, we present information on our data sources. In addition, we provide summary graphical information on USMC vehicle-related deaths for fiscal years (FY) 1999 through 2007. The information we present here provides a general sense of trends and introduces issues of concern that are explored more fully in the later analyses.

Data sources

The data we use combine information from four sources. The Naval Safety Center maintains the formal records on USMC accidental deaths. However, their records offer little of the demographic information that we need to identify individual risk factors. For this information, we rely on USMC personnel records. For basic demographic and career data, we draw on the Headquarter Master Files (HMF). These files, maintained at CNA, provide a snapshot of USMC personnel at the end of each quarter. The data include both demographic characteristics (e.g., birth date, sex, race, and marital status) and career information (occupational field, command, rank, and deployment status). We combine this with data from CNA's ARSTAT files to capture information on losses (retirement, end of enlistment, and death). We also draw on CNA's Street-to-Fleet file, which records accession data. This file provides us with information on waivers (for traffic, alcohol, drug, or criminal offenses) that are granted during enlistment.

Although the personnel files include information on fatalities, we can't reliably identify vehicle-related deaths from personnel files alone. One problem arises from the practice of discharging Marines facing imminent death under a temporary disability retirement (a practice that allows additional benefits for family members). Such cases can not be distinguished from other disability retirements. Instead, we used Safety Center records to identify fatalities and matched those records to specific individuals in the personnel files. It is a challenge to make such matches because the Safety Center did not retain social security numbers (SSNs) in their records until FY 2004 (and even though SSNs were retained in later years, there are inaccurate entries). Luckily, by using the personal information that is available in the Safety Center files (date of mishap, age, sex, rank, occupation), we were able to reliably match all the fatalities to specific individuals in the personnel files. Merging the Safety Center data also gave us some additional details on the circumstances of death (e.g., time of death) that we consider in the summary analyses.

For the later statistical analysis, we use data covering the identified fatalities and a representative sample (5 percent) of other Marines serving between October 1998 and September 2007. The inclusion of these other Marines is important in providing a comparative baseline against which to evaluate whether an apparent risk factor is in fact associated with higher probability of death. Of course, the statistical analysis can only make use of data that is generally available for all Marines. While there is much valuable information collected when an accident occurs (e.g., alcohol use, protective equipment), with no comparable information for individuals in the population as a whole, we can't assess how such factors affect overall USMC risks.

Because we have Safety Center data on all vehicle accidents, our initial plan was to consider serious motor vehicle accidents along with fatalities. The larger numbers of these accidents would have strengthened the statistical significance of our results. However, the limited reporting of SSNs made that approach impractical. We were left with few years of data on non-fatal accidents, and we have doubts about how complete or representative the data are that we do have.

Summary statistics on USMC vehicle deaths

Annual trends in USMC vehicle fatalities and fatality rates

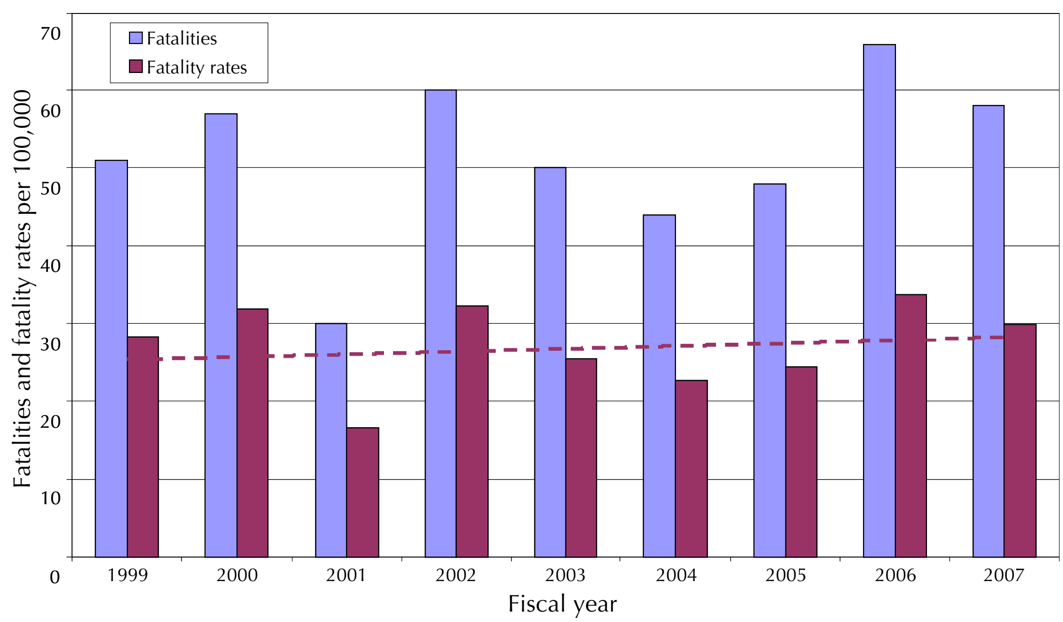
Our data include 464 identified vehicle-related deaths for FY 1999 through FY 2007. The data exclude deaths related to operational vehicles. They include automobile and motorcycle deaths, along with a few pedestrian and off-road vehicle incidents. Table 1 shows the number of deaths annually by type of vehicle, distinguishing motorcycle from other vehicle-related (primarily automobile) deaths.

Table 1. Vehicle-related deaths annually (FY 1999–FY 2007)

FY	Motorcycle	Other vehicle	Total
1999	6	45	51
2000	7	50	57
2001	5	25	30
2002	10	50	60
2003	17	33	50
2004	6	38	44
2005	13	35	48
2006	17	49	66
2007	19	39	58
Total	100	364	464

Figure 2 shows the number of deaths and fatality rates per 100,000 Marines by year. Fatalities reached a new high in FY 2006 after three years of improvement that followed a FY 2002 spike. The dashed line shows the trend in fatality rates. There has been 1.3 percent annual rate of increase in vehicle fatalities. The slight upward trend reflects an increase in motorcycle deaths that offsets a decline in other vehicle deaths.

Figure 2. Trends in USMC Corps vehicle-related fatalities

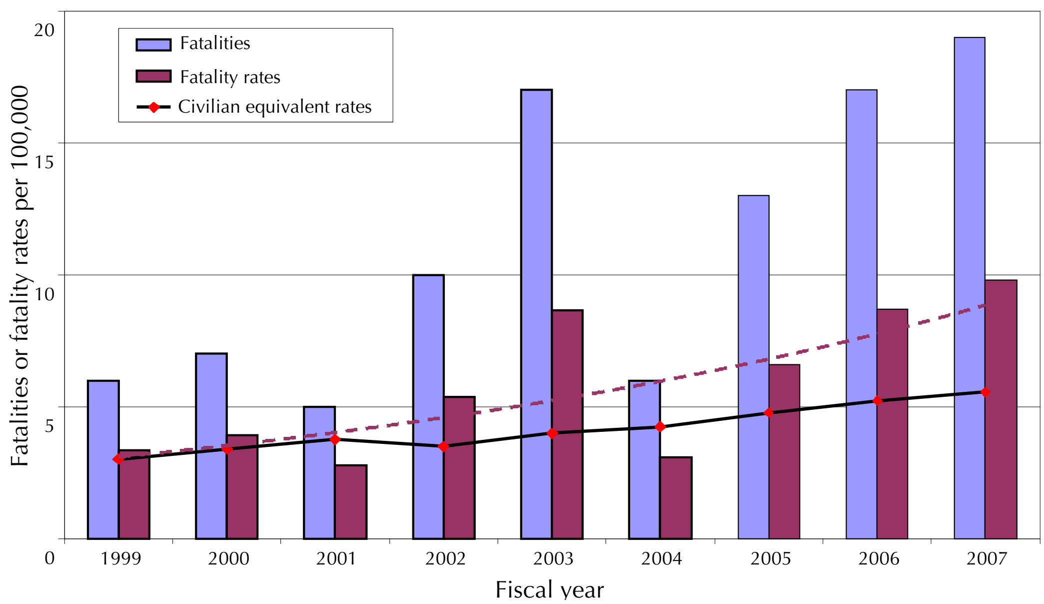


The overall vehicle fatality rate for Marines compares favorably to that for a comparable civilian population. Vehicle death rates for the equivalent civilian population (adjusted to the age and gender mix of the USMC) have been relatively stable at about 34.5 deaths per 100,000.[2] The USMC has averaged 29 deaths per 100,000 over the same period. Of course, it is hard to make a true comparison that accounts for differences in lifestyles and miles driven.

Motorcycle fatality trends

Figure 3 show the trends in motorcycle-related fatalities. The growing problem with motorcycles is obvious. Fatality rates have increased 13 percent annually (dashed line). This increase more than offsets the decline of 1.5 percent per year in USMC automobile fatalities.

Figure 3. Trends in USMC motorcycle fatalities



It's important to put the motorcycle deaths in context. There has been a nationwide increase in motorcycle deaths since 1997; the recent surge has become the subject of newspaper articles [4]. Unfor-

2. Civilian rates are derived from National Highway Transportation Safety Authority, Fatality Analysis Reporting System data. The data are available at *ftp://ftp.nhtsa.dot.gov/fars/*.

tunately, the rate of increase for the USMC far exceeds what is being seen in the civilian world. The solid line in figure 3 shows the trend in motorcycle fatality rates for a comparable civilian population (again adjusted to reflect the age and gender mix of the USMC). Until 2001, USMC motorcycle fatality rates closely matched civilian rates; they now exceed equivalent civilian rates by 70 percent.

The drop in motorcycle fatalities in FY 2004 is noteworthy and not well understood. It would be interesting to explore whether this one-year decline was related to command-level attention following the preceding high-fatality years. An alternative hypothesis, that the decline is related to high deployment levels, doesn't seem to fully square with the fatality rates seen in other years of high deployment.

Vehicle fatality rates by age (FY 1999–FY 2007)

The likelihood of a vehicle-related death typically has a strong relation to age. We expect automobile death rates to be high for 18 to 21 year olds, and then decrease with driving experience and age. This proves true for the USMC and the general population, as shown in figure 4.

Figure 4. Other vehicle (non-motorcycle) fatality rates by age

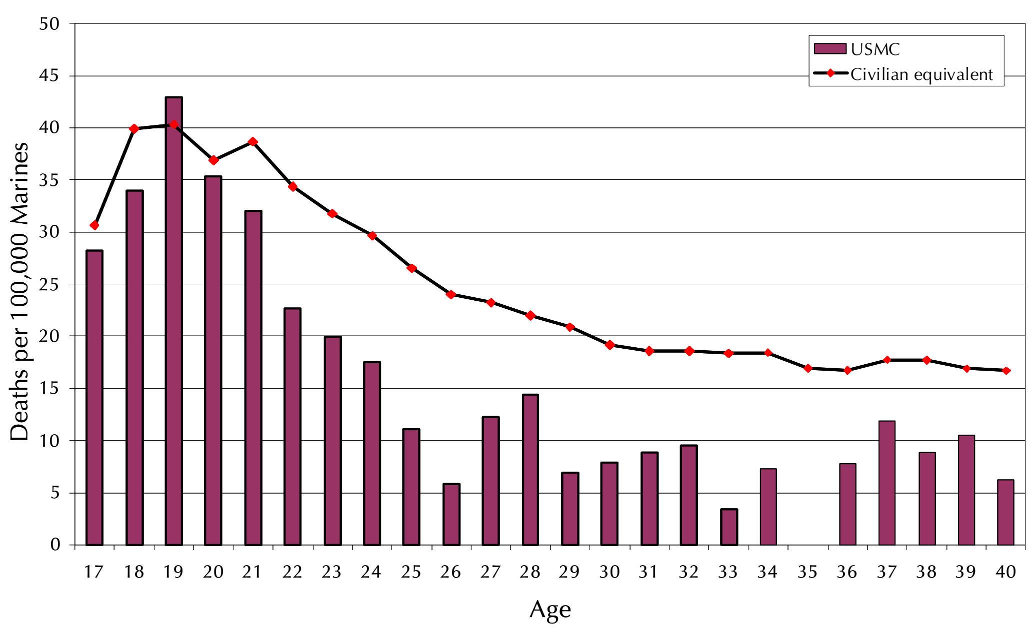
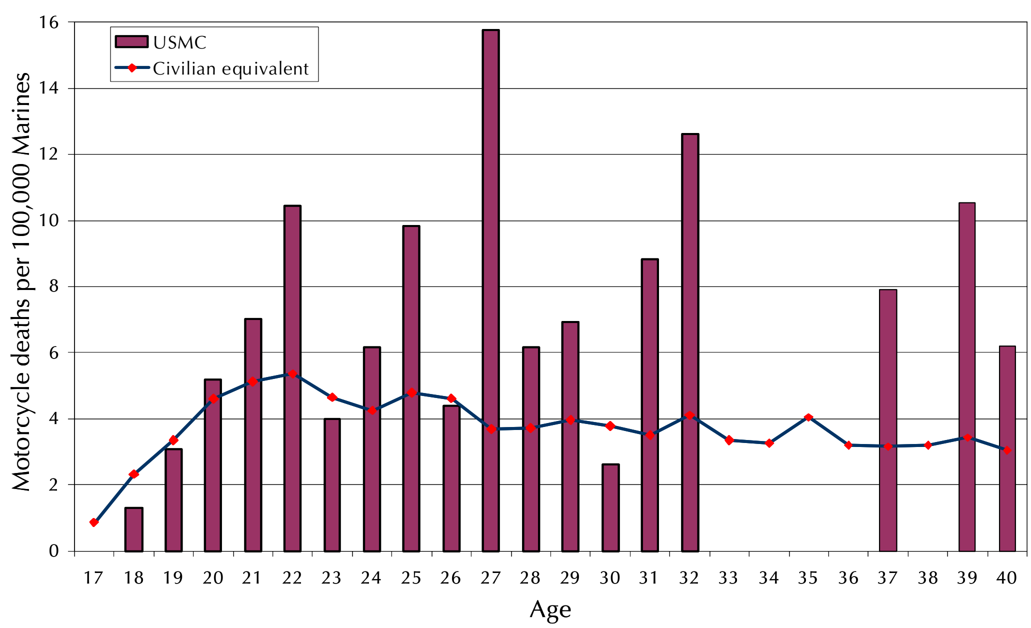


Figure 4 shows non-motorcycle vehicle fatality rates, by age, for the USMC and for an equivalent civilian population. For both civilians and Marines, motor-vehicle fatality rates are highest for 19 year olds and then decline rapidly with age. The relative difference in fatality rates between civilians and Marines is interesting. By age 22, the USMC automobile death rates are much lower than those of civilians. The USMC would have seen 40 percent more automobile deaths, in total, if they matched these civilian rates.

Motorcycle fatality rates by age

Motorcycle fatality rates exhibit a rather different pattern with respect to age. Motorcycle fatality rates tend to peak at a later age and decline more slowly. Figure 5 shows the USMC and equivalent civilian motorcycle fatality rates. In contrast to what we see for automobiles, USMC motorcycle death rates are generally well above those for civilians. The high fatality rates among individuals aged 25 to 32 are particularly troubling, since these individuals set an example for younger Marines. Keep in mind that figure 5 reflects average fatality rates for the last 9 years. The recent increase in USMC motorcycle fatality rates makes this comparison much worse.

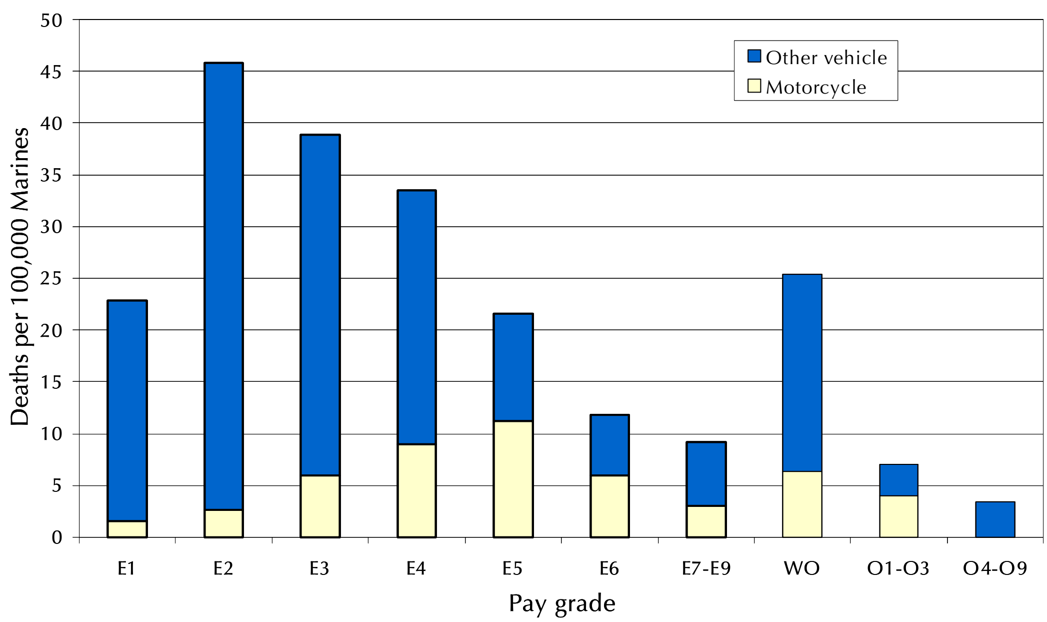
Figure 5. Motorcycle fatality rates by age



Vehicle fatality rates by pay grade

Vehicle fatality rates by pay grade (see figure 6) largely mirror those by age. Overall vehicle fatality rates peak at the E2 grade level and then decline rapidly with higher rank. In contrast, motorcycle fatality rates peak at the more senior E5 grade. Low fatality rates for the E1 grade no doubt reflect limited driving experience and the restricted liberty and driving privileges for new Marines. The anomalously high fatality rate among warrant officers is interesting. But, for such a small group, even a single death can have a large effect. The motorcycle fatality rates for junior officers (O1–O3) exceed those for senior enlisted (E7–E9). Although there is reason for concern, it must be noted that there has been no more than one motorcycle death a year among the officers.

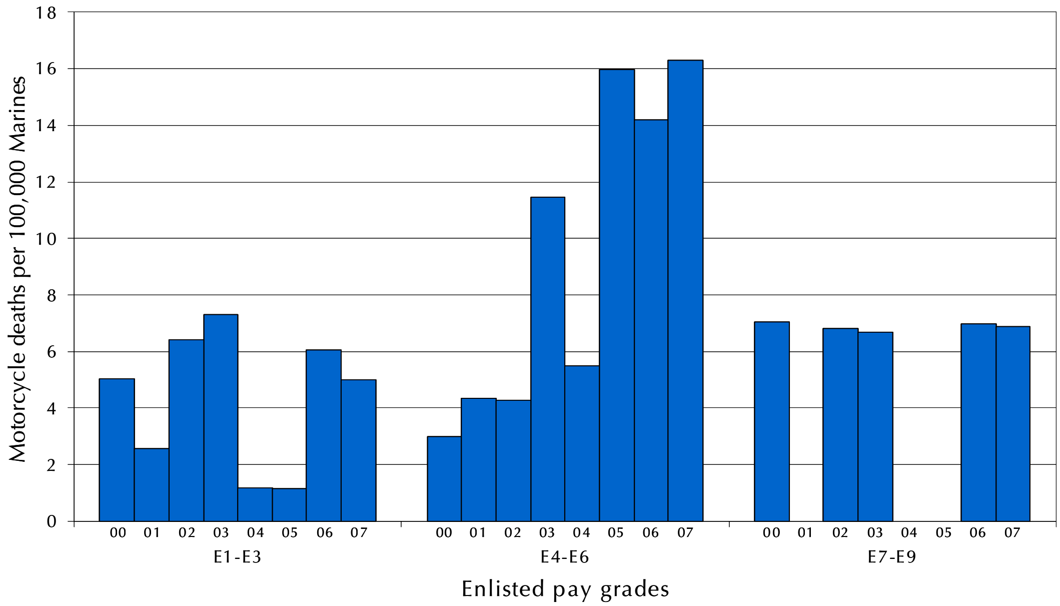
Figure 6. Vehicle fatality rates by pay grade



Trends in motorcycle fatality rates by pay grade

Of interest are the changes that occurred over the time period. Figure 7 shows the annual trends in motorcycle fatality rates by enlisted pay grade. There has been a dramatic 25 percent annual rate of increase in motorcycle fatality rates for the mid-level (E4–E6) enlisted pay grades over these years. These same increases are not occurring among other enlisted personnel.

Figure 7. Trends in motorcycle fatality rates by enlisted pay grades



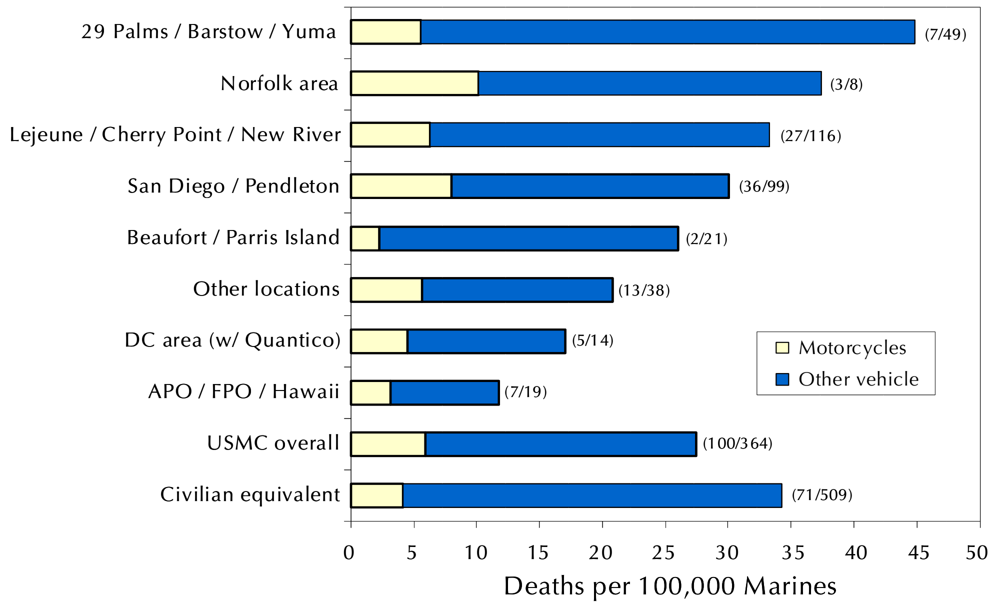
Vehicle fatality rates by location

Our previous study looked broadly at the difference in death rates between urban and rural locations. In this study, we look in more detail at fatality rates for specific locations with the hope that this might help identify effective safety programs.

Figure 8 shows vehicle fatality rates for several regions where there are significant concentration of Marines. The figure shows both motorcycle and other-vehicle fatality rates. The numbers in parentheses indicate the actual numbers of deaths (motorcycle/other vehicle) observed over the nine-year period. We included locations with at least ten deaths. For comparison, the figure also shows average fatality rates for the USMC and the equivalent civilian population. The numbers listed after the civilian rates are the deaths that might be expected if the USMC population had matched civilian fatality rates.

The highest overall fatality rates are for individuals assigned to the 29 Palms/Yuma/Barstow bases. Automobile death rates are particularly high in these rural areas. The Norfolk area also shows high fatality rates, although this can probably be discounted since more than half of the Norfolk area deaths occurred in a single year (FY 2001).

Figure 8. Average fatality rates by location (FY 1999–FY 2007)

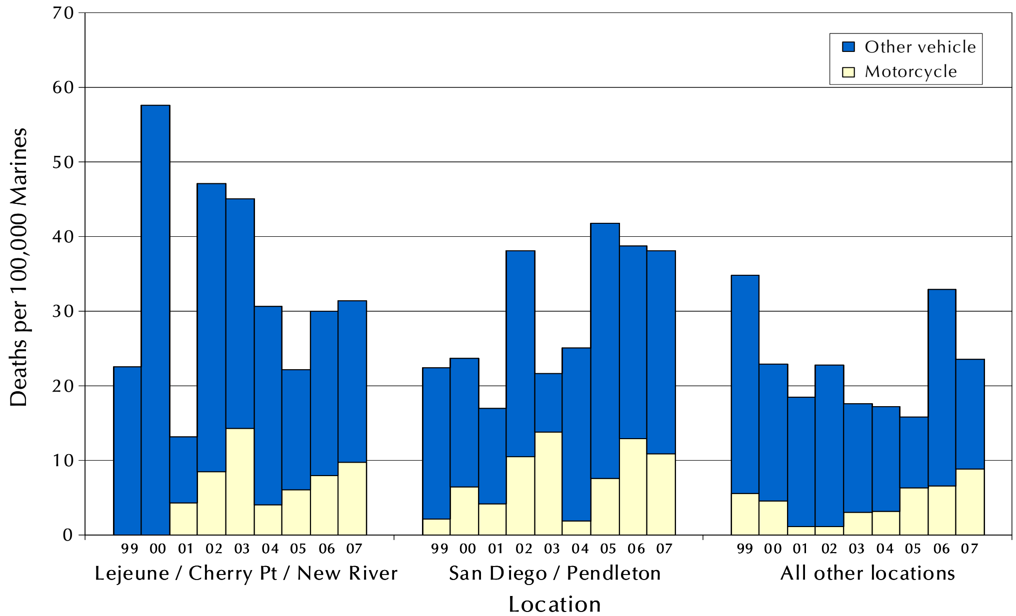


Of primary interest are the Camp Lejeune and Camp Pendleton areas, each of which accounts for a quarter of the USMC population. Both have overall vehicle fatality rates above the USMC average, with the North Carolina bases rather worse. Motorcycle deaths have been a problem on the urban roads of Southern California; automobile deaths have been the bigger problem on the more rural roads of North Carolina. This pattern may be changing, as we will see next.

In figure 9, we show the annual trends in fatality rates for the Lejeune and Pendleton regions. Since FY 2001, motorcycle death rates have largely equalized across the two locations. Note the distinctive and matching saw-tooth pattern of motorcycle fatality rates. The sharp FY 2004 drop in motorcycle deaths seen at these two locations is not apparent elsewhere.

Overall, there seems to have been a modest decline in fatality rates at Lejeune, with automobile rates down while motorcycle deaths are up. Camp Pendleton is getting worse, with both automobile and motorcycle death rates increasing. The increase in automobile death rates at Pendleton is a trend not seen elsewhere. We explore these location specific changes further in the statistical analysis.

Figure 9. Trends in fatality rates by location (FY 1999–FY 2007)



Fatality rates by MOS

There are some pronounced differences in the vehicle fatality rates among occupational fields. Figure 10 shows the fatality rates for several of the larger groups. These groups comprise almost 80 percent of the USMC population. The highest vehicle-related death rates are in avionics (fields 63 and 64), aircraft maintenance (60–62), and motor transport (35). Their rates are almost matched by the infantry (03). Other occupational fields with high death rates are field artillery (08), engineers (13), and supply administration (30). Motorcycle death rates are highest for field artillery, infantry, and aircraft maintenance. The motorcycle rates are also high for personnel and administration (01) and motor transport. The differences in death rates across occupations might indicate that some fields draw people who are more likely to take risks or that certain jobs present the opportunity for greater risk (e.g., more free time).

Figure 11 looks at recent trends in fatality rates for three major groupings: infantry (03), the combined aircraft maintenance and avionics fields (60–64), and motor transport (35). The three groups account for over 35 percent of the USMC population.

Figure 10. Average fatality rates by occupational field

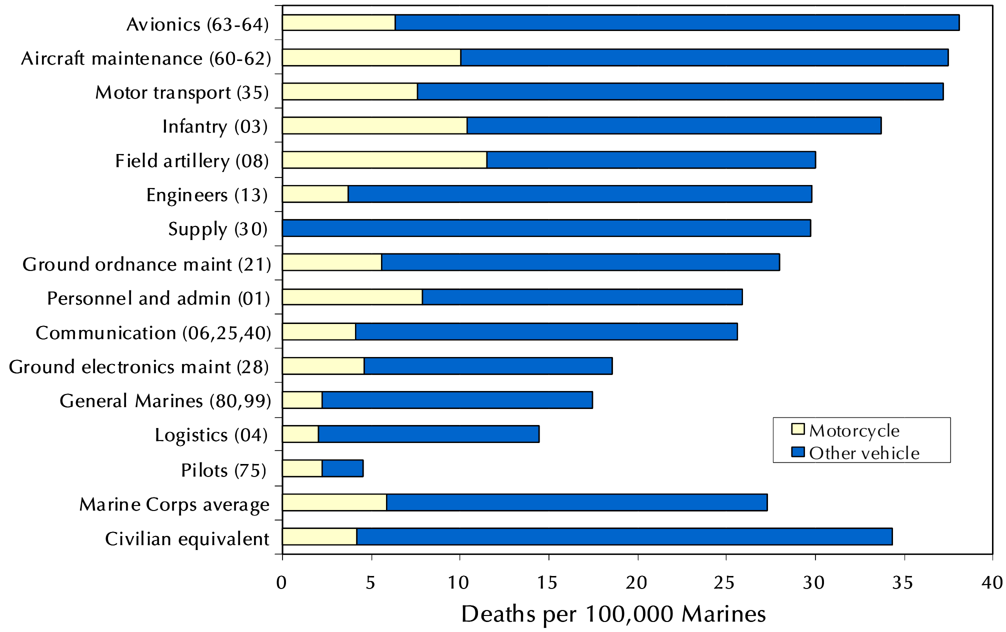
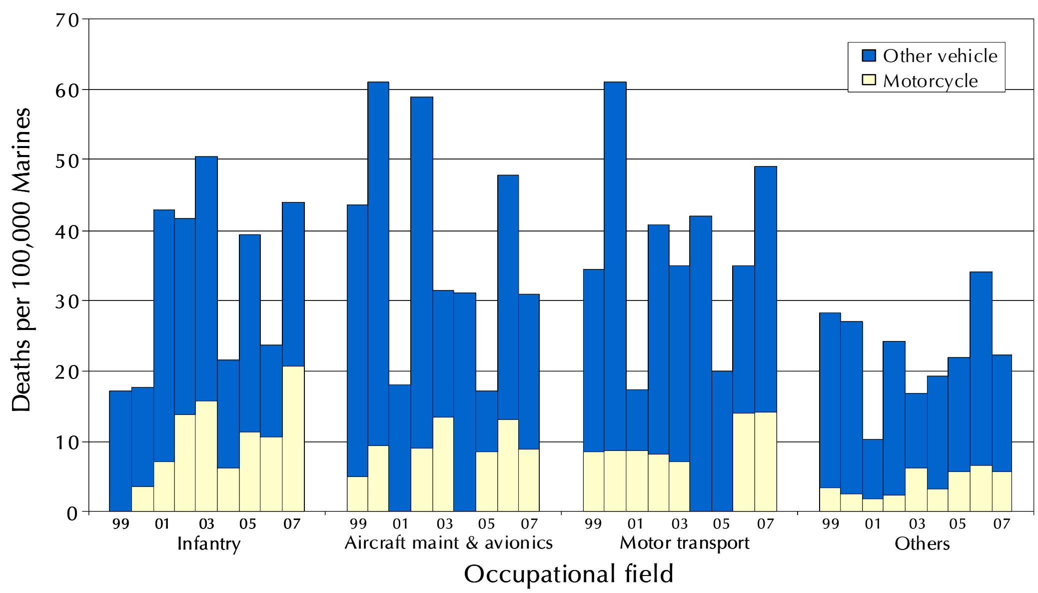


Figure 11. Trends in fatality rates by occupational field

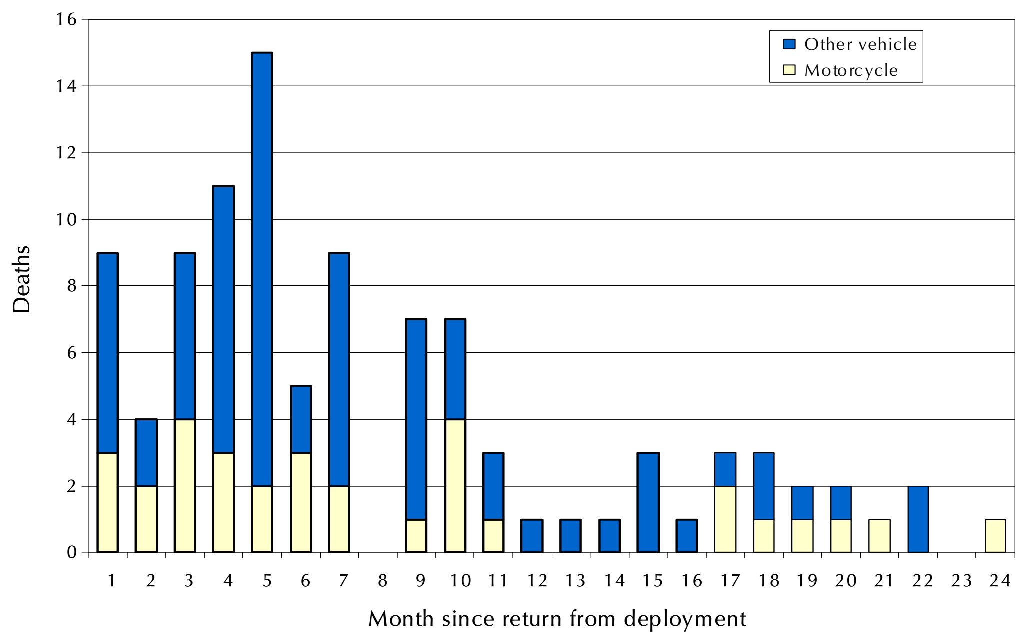


We see in figure 11 that fatality rates for the infantry have been increasing, with both motorcycle and automobile deaths contributing to that rise. Their pattern of increase very much mirrors what we saw for Camp Pendleton. The aircraft maintenance and motor transport groups have historically high fatality rates. They are getting no worse. The other occupational fields, in total, show relatively low fatality rates and little indication of problematic trends.

Fatalities following deployment

In figure 12, we show frequency of vehicle-related death following deployment. There is a period of high risk in the year after deployment. The number of fatalities peaks 4 to 5 months after deployment and then declines. Motorcycle deaths don't appear to be as strongly related to deployment as automobile deaths do.

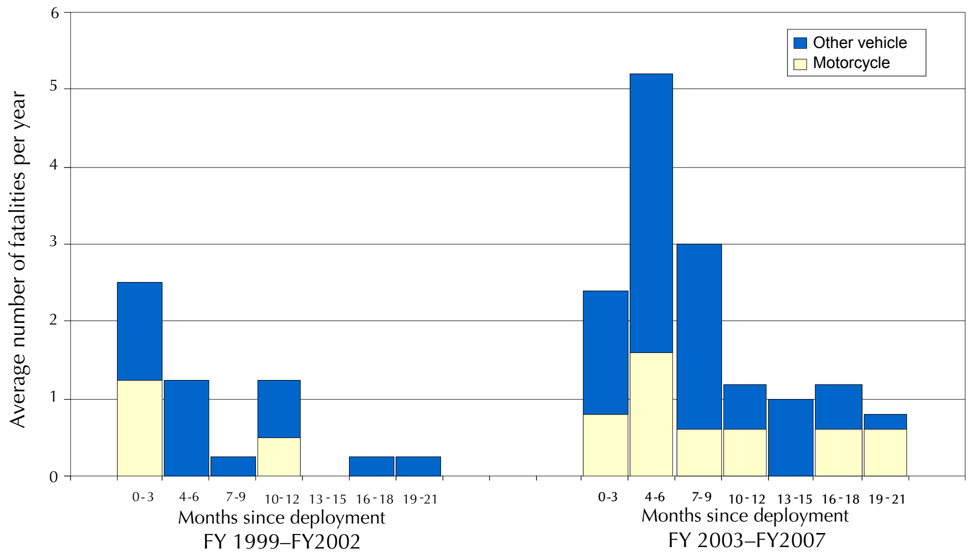
Figure 12. Frequency of vehicle fatalities following deployment (FY 1999–FY 2007)



Note that we do have some concern with the accuracy of deployment return dates. Prior to deployment, return dates are entered in the HMF files as estimates. Once deployment has actually ended, a corrected date is entered in the subsequent quarterly files. However, quarterly personnel files usually do not include individuals whose service ends during that quarter (e.g., those who die). As a result, we may not see the correct end-of-deployment date for those who die within 3 months of deployment. However, this should not greatly affect any conclusions.

In figure 13, we look at the trend in post-deployment fatalities. The number of fatalities in the months after deployment has risen substantially since FY 2002.

Figure 13. Trends in vehicle fatality rates following deployment



Of course, with higher levels of deployment, and larger number of individuals subsequently returning from deployment, it is not surprising that post-deployment deaths have increased. By FY 2003, the number of individuals deployed was two to three times higher than seen in earlier years. Still, the distinct spike in deaths within 9 months of return from deployment calls for attention.

Motor-vehicle fatality rates by time of day

The timing of motor vehicle accidents for the USMC differs somewhat from that for civilians. In figure 14, we present vehicle fatality rates by time of the day for Marines and the equivalent civilian population. Similarly, figure 15 shows motorcycle fatality rates by time of day.

The USMC continues to have vehicle fatality rates above those for civilians during the morning rush hours of 0600 to 0759. The difference in rates is less extreme than was seen in the earlier study, but does suggest that Marines are still taking risks to ensure that they make muster. In the previous study, we saw death rates between the hours of 0300 and 0500 almost twice as high as the equivalent civilian rate. That is no longer true. The death rates in these early morning hours are now very much in line with equivalent civilian rates. The high USMC death rates at midnight and 0200 are often related to alcohol use and fatigue.

Figure 14. Vehicle-related fatality rates by time of day

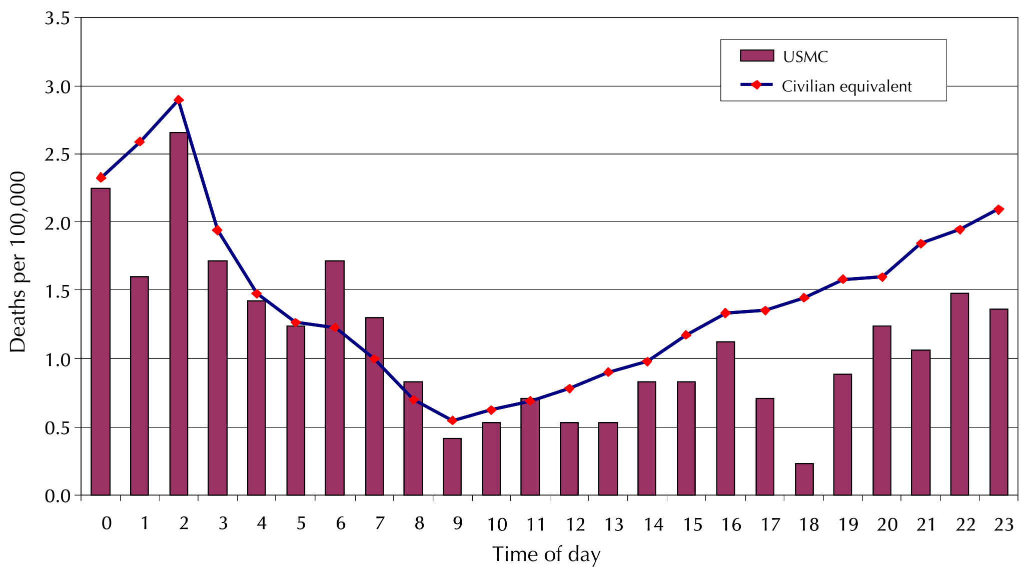
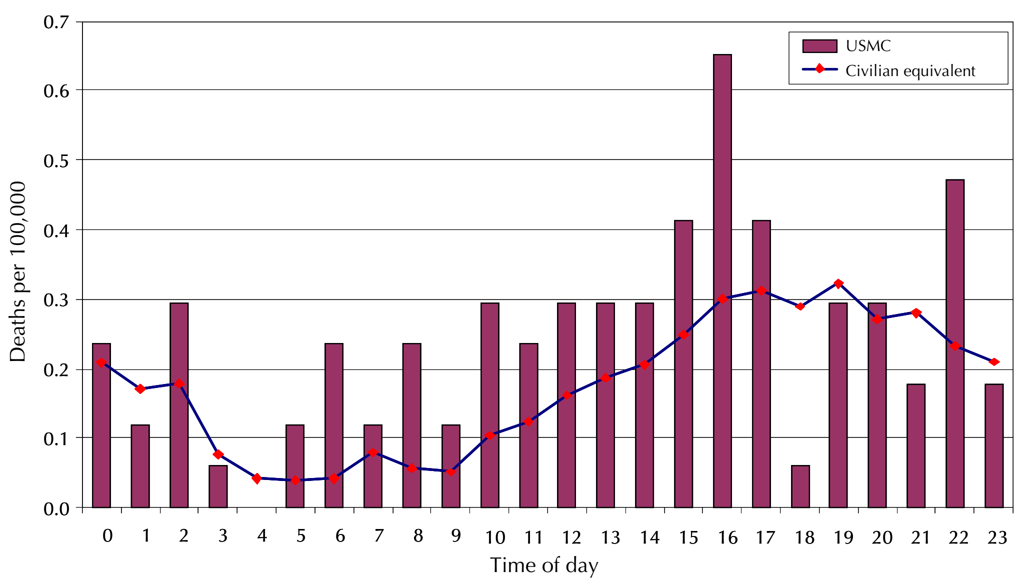


Figure 15. Motorcycle fatality rates by time of day

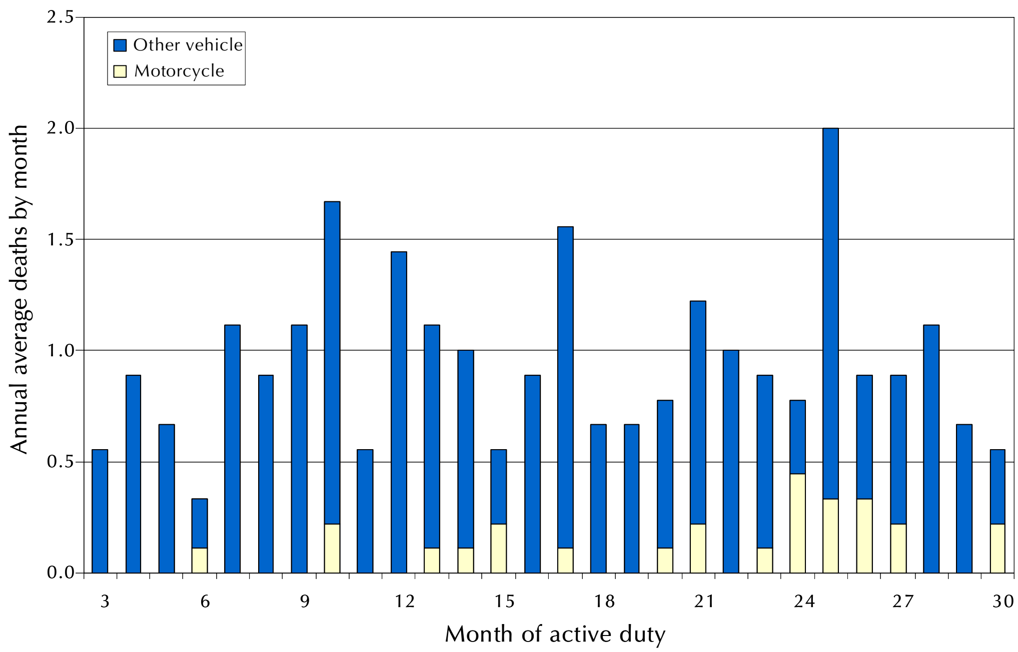


Motorcycle fatalities happen most frequently in the afternoon. This is a pattern generally consistent with what is seen for civilians. It is suggestive of recreational use, rather than commuting. USMC motorcycle fatality rates are, at most times, higher than equivalent civilian rates.

Fatalities by time in service

Frequency of death varies by duration of service. Figure 16 presents the average number of fatalities for an annual cohort of new Marines, by months of service.

Figure 16. Frequency of accidental death by duration of service



The figure gives some sense of the profile of risk by duration of service. It appears that risk is relatively low early in a career, perhaps due to stringent restrictions on liberty. (There were no deaths identified in the first twelve week of service, which are spent in boot camp.) At about 7 months, there is a sizable jump, possibly associated with a loosening of restrictions or upcoming deployments. Risk remains high throughout the remainder of the first year (except for an unusual drop at 11 months). The increases in fatalities that we see at around 17 and 25 months are perhaps associated with deployments. In the earlier study, we saw similar increases at these times, although the spikes were less pronounced.

The techniques we present in the next section are explicitly designed to explain survival time data like that depicted in figure 16. The techniques allow us to determine the individual factors that best explain the frequency and timing of death.

Hazard models of vehicle deaths

The data discussed in the previous section provide a sense of the vehicle deaths in the USMC and illustrate some trends and important comparisons. In and of themselves, they provide insight into what may be associated with accidents and some guidance for accident prevention programs. However, they do not allow us to completely unravel the many factors associated with fatal accidents. For example, though the infantry has a high fatality rate, we cannot tell whether that reflects a concentration of younger single males, or if there are other specific characteristics of infantrymen that, all else being equal, are associated with higher risk. To separate the effects of the various characteristics, we employ statistical analyses.

Hazard rate models

We use a hazard rate model to conduct our analyses of factors associated with deaths. In this section, we describe the approach and explain why it is an appropriate technique.

Background

In figure 16, we showed time-to-death for a typical cohort of Marines, which is the type of information we would like to be able to explain. Fortunately, there are techniques designed explicitly to deal with such duration data. These techniques are used in various fields including: industrial engineering, where time-to-failure of equipment is of interest; medicine, where survival time following treatment is critical; and economics, where researchers have looked at the duration of underemployment.[3] In the current context, the approach is to model the probability that a particular individual will die in vehicle accident, given that others at potential risk survive.

3. The techniques are often referred to as survival analysis. References [2] and [3] provide introductions to the methods.

In dealing with duration data, the hazard rate models are preferred to other standard regression techniques [2]. In particular:

- Hazard rate models explicitly account for the complex stochastic process that underlies survival times.
- Hazard models specifically address data truncation. That is, they account for the fact that individuals were still at risk before and after the time covered by available data. By addressing this, hazard rate models avoid biased estimates.
- The approach easily deals with time-varying characteristics. In the hazard model, characteristics are re-evaluated at each point in time. Designing a standard regression approach to explain survival time in this manner would present a challenge.

More generally, the method allows us to look systematically at separating out the effects of complex combinations of risk factors. Although the graphical techniques of the previous section can provide insight, they become overwhelming if we try to use them to unravel the many factors and combinations of factors that might be associated with fatal accidents.

Modeling assumptions and techniques

The model asserts that the risk of a death occurring at age t for an individual is a function of their age and personal characteristics:

$$\begin{aligned} h(t) &= h_0(t)\exp(X\beta) \\ &= h_0(t)\exp(x_1\beta_1)\exp(x_2\beta_2)\exp(x_3\beta_3)\ldots\exp(x_n\beta_n) \end{aligned}$$

This is called the hazard function. The function $h_0(t)$ describes how the baseline risk varies with age; the expression $\exp(X\beta)$ expresses how risk increases or decreases with changes in a set of variables X, which describe the characteristics of the Marine at that point in time. This particular multiplicative specification means that the proportional effect of an increase in X does not depend on age.

The purpose is to determine how each characteristic affects risk. We estimate a set of coefficients (β) for the variables in the model so as to best fit the observed data. Specifically, we select the coefficients that maximize the predicted likelihood of observing those deaths that actually occurred. To do so, we maximize the function

$$L(\beta) = \prod_{k=1}^{K} \left(\frac{\exp(X_k \beta)}{\sum_i \exp(X_i \beta)} \right)$$

where, for each fatal accident (*k* in the equation), the numerator reflects the characteristics of the particular Marine who died, and the denominator reflects the set of all Marines who are the same age.

Interpreting results

The model estimates how a set of demographic and career variables affect risk. Results can be expressed either as *hazard rates* or as *coefficients.* The estimation determines the coefficients β_i. Hazard rates are calculated as $\exp(\beta_i)$. We will generally discuss hazard rates, rather than the coefficients. The hazard rate compares the risk for two people who are the same except for a unit difference in one particular characteristic. A hazard rate of 1 indicates that the risk is not appreciably different for Marines with that characteristic than for those without. A value of less than 1 indicates lower risk. Similarly, values above 1 indicate higher risk.

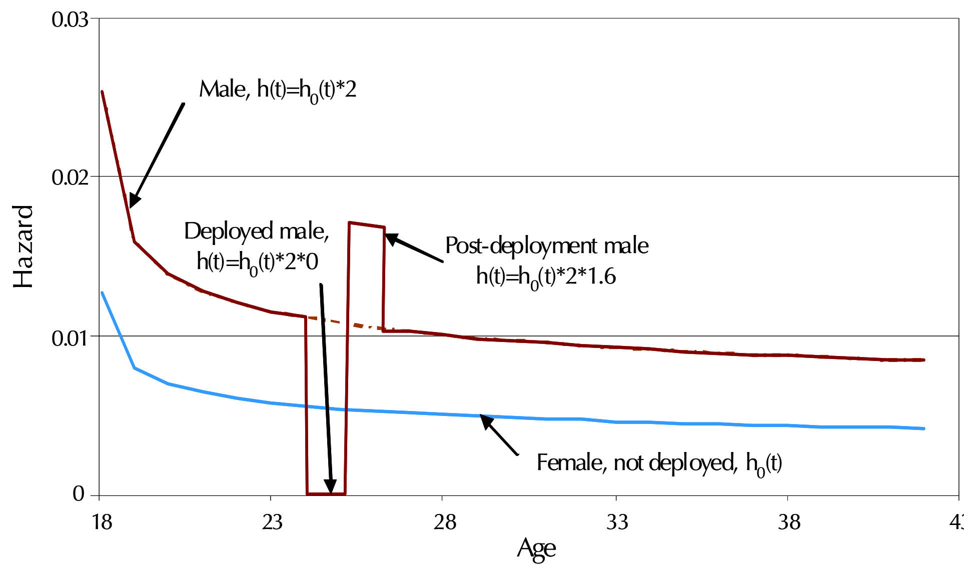
In figure 17, we illustrate a hazard function and the effect of hazard rates. In the example, we consider three characteristics: whether an individual is male or female, whether he or she is deployed, and whether he or she is recently back from deployment. The lower curve shows the baseline hazard function $h_0(t)$, which gives the probability of death,[4] by age, for an individual with none of the three characteristics (i.e., not male, not deployed, and not just back from deployment). As might be typical for automobile deaths, we show a hazard that declines with age.

Suppose the hazard rate for the characteristic "male" is 2. The hazard function for males would then be represented by the upper curve,

4. Strictly speaking, this is a conditional probability—the probability of death at a particular age, given that the individual has survived so far.

with a probability of death twice that for females. Now, suppose that the hazard rate while deployed is 0 (with no risk of personal vehicle accident while deployed). The hazard function for the deployed male would shift down for the period of deployment, as shown. Similarly, let us assume that the post-deployment hazard rate is 1.6. A male returning from deployment then faces a combined hazard of 3.2 (2 for male multiplied by 1.6 for post-deployment) for a period of time after deployment. The key points are that hazard rates may be permanent or transitory; they are multiplicative in their effect; and their values are defined relative to a particular set of baseline characteristics.

Figure 17. Interpreting the hazard function and hazard rates



Data issues

Our analysis covers all enlisted Marines who served from October 1998 through September 2007 and includes 453 identified fatalities. The size of this dataset presented a challenge. Over 500 thousand Marines served during the period. With quarterly observations on each individual, there were almost 7 million observations in total. To make the analysis manageable, we drew a 5 percent sample to represent the Marines who did not die. That sample is weighted in the analysis to represent the full population. (All of the fatalities are included in our analysis.)

Although the data we have provide a rich basis for analyses, there are limitations related to the use of quarterly data. These data are typically available only while the individual is still in the USMC. Thus, there is no record of changes in status that occur during the quarter when an individual leaves (or dies). We were forced to assume that characteristics do not change between the end of the last quarter observed and the date of separation. The exception is that we have information from loss records on the location and monitored command of individuals at their date of separation.

The nature of the quarterly snapshot also means that information on changes that occur within a quarter is lost. For example, suppose a Marine finishes recruit training, moves through training school, and then enters another command all within the same quarter. Our data record only that latest command and the date that tour began. Thus, we miss some of the individual's history. We do take advantage of the dates that are available. These include latest date of rank, date current tour began, deployment end date, active duty base date, and date of attrition.

Data are also missing for individuals who separate before the end of their first calendar quarter in the USMC. If a death occurred in those early months, we would have no information on the Marine who died. Even if we obtained this information from other sources, there remains a potential for bias because the control group is missing others who separate early (e.g., those who wash out of boot camp). Luckily, no vehicle-related deaths occur in that first quarter of service—since no one drives during their first twelve weeks spent in recruit training.

Deployment dates present another challenge. The quarterly personnel data provided us with an end-of-deployment date, but not the start date for deployment. It is important that we account for the period of deployment, since this is an interval when individuals are not at risk for private vehicle accidents. We have estimated the start of deployment based on unit deployment data. To do so, we calculated the average deployment length for units returning in each month. The averages were then used to estimate a start of deployment for the individuals in our sample, based on the month their deployment ended. Obviously, the estimated dates are not always accurate, but hopefully they provide a reasonable approximation.

A final caution is related to the small number of fatalities. Although we have a large sample from the Marine Corps as a whole, there are relatively few deaths (453 overall and only 94 motorcycle deaths). This means that any single death is potentially influential in determining the estimated risks.

Estimating risks for all vehicle-related deaths

The first model we discuss evaluates the risk of overall vehicle-related deaths. Later, we look more specifically at motorcycle deaths,[5] and after that, we examine whether risks have changed over time.

The estimation results for the model of all vehicle-related deaths are listed in table 2. The first column gives the hazard rate, which represents the relative risk associated with the variable. The second presents the p-values (a measure of statistical significance).

When interpreting results, it is important to consider their statistical significance. The p-value indicates how sure we can be that the hazard rate differs from 1. Typically, researchers consider coefficients with p-values of less than 0.10 to indicate that the hazard associated with this variable does differ from the baseline level.

Key risk factors—results for all vehicles

Here we describe noteworthy results. Many of these results match intuitive expectations as to who is more likely to engage in risky behavior; others are more surprising.

Males have high risk / females aged 19 to 20 have higher risk

Controlling for other factors, we find that male Marines are at higher risk than most female Marines. This result is not surprising—accidental deaths, and particularly motor vehicle deaths, are more common among males than females in the United States.

5. We also looked at non-motorcycle deaths; those results are in appendix A.

More surprising is the high risk facing females aged 19 or 20. This is something we did not see in the earlier study. That group accounts for 2.1 percent of deaths, despite making up only 1.4 percent of the USMC population.

Table 2. Estimation results for the risk of vehicle deaths

	Hazard rate [a]	p-value [b]
Location		
Lejeune / Cherry Point / New River	1.77	0.00 ***
San Diego / Camp Pendleton	1.69	0.00 ***
29 Palms / Barstow / Yuma	2.01	0.00 ***
Beaufort / Parris Island	2.58	0.02 ***
DC area (w/ Quantico)	1.21	0.30
Norfolk area	2.16	0.01 **
Occupational field		
Personnel and admin (01) & finance (34)	1.08	0.74
Aircraft maintenance & avionics (60–64)	1.57	0.01 ***
Pilots (75) & aviation support (70, 72, 73)	0.69	0.36
Infantry, artillery, armor (03, 08, 18)	1.32	0.06 *
Communications & data systems (06, 25, 40)	1.10	0.65
Engineers (13)	1.21	0.42
Motor transport (35)	1.50	0.04 **
Supply (30) & aviation logistics (66)	1.38	0.14
Race/ethnicity		
Hispanic	1.11	0.48
Black	0.93	0.87
Other non-White race	1.01	0.96
Physical fitness		
Physical fitness class 1 (high pass)	0.61	0.00 ***
Physical fitness class 2 (med pass)	0.65	0.01 ***
Physical fitness class 3 (low pass)	0.39	0.00 ***
Pay grade / time in service		
E1 to E2 – in boot camp	0.00	0.00 ***
E1 to E2 – week after boot camp	2.79	0.12
E1 to E2 – 3 to 6 months since joining USMC	0.77	0.63
E1 to E2 – 6 months or more since joining USMC	2.48	0.05 **
E3 to E4	1.76	0.20
E5 to E6	1.37	0.45
Warrant officers	4.20	0.02 **
Career events		
3 months or less since reporting to command	0.38	0.00 ***
3 to 6 months since reporting to command	0.83	0.21

Table 2. Estimation results for the risk of vehicle deaths (cont'd)

	Hazard rate [a]	p-value [b]
Career events (cont'd)		
Promoted within last 3 months	0.54	0.00 ***
Demoted within last 3 months	0.76	0.53
Demoted 3 to 6 months ago	1.35	0.42
Prior military legal action	1.23	0.66
0 to 3 months since deployment	0.85	0.49
3 to 6 months since deployment	1.60	0.02 **
6 to 9 months since deployment	1.11	0.68
Deployed	0.00	0.00
6 months or less since reenlistment	1.00	1.00
6 to 12 months since reenlistment	1.38	0.31
Miscellaneous demographics		
Male	2.47	0.02 **
Female, age 19–20	2.81	0.04 **
Single with no dependents	1.39	0.02 **
Within a year after divorce	0.30	0.24
Within a year after marriage	0.60	0.04 *
On temporary duty	0.75	0.06 *
Living on base	1.21	0.28
Education and test scores		
More than high school education	0.55	0.24
High school equivalency or less	0.95	0.85
AFQT score 1 to 40	0.78	0.08 *
AFQT score 85 to 99	0.72	0.08 *
Enlistment waivers		
Traffic waiver	1.13	0.68
Serious non-traffic waiver	1.02	0.94
Minor non-traffic waiver	1.30	0.44
Drug or alcohol waiver	1.26	0.02 **
Felony waiver	1.31	0.39
Time		
Apr–Jun quarter	1.70	0.00 ***
Jul–Sep quarter	1.84	0.00 ***
Oct–Dec quarter	1.73	0.00 ***
Quarterly time trend	1.01	0.15

a. For categorical variables, hazard ratios are interpreted relative to the categories not listed. For example, the Black and Hispanic values are relative to Whites and occupational values are relative to individuals in the fields not explicitly listed. See appendix B for details.

b. *** significant at 1%, ** significant at 5%, * significant at 10%.

Being single with no dependents increases risk

We included a variable that represents the risk associated with being single and having no dependents. The results indicate that individuals who are single with no dependents have a 54 percent higher risk than those who are married or have dependents. This may reflect a change in behavior patterns with marriage and parenthood.

Race and ethnicity

We see no indication that racial or ethnic grouping has a significant effect on the risk of fatal vehicle accidents. This is in contrast to the results of our earlier study, where it was found that Blacks and Hispanics had risks at least 30 percent higher than Whites.

Aircraft mechanics, motor transport, and infantry have higher risks

We included variables to identify a number of major occupational groups. The groups are more aggregated than those considered in the earlier study. This was done partly to deal with the consolidation and renumbering of occupational codes that has occurred in recent years. We also wanted to avoid some of the distinctions previously made between what should be similar groups of individuals (e.g., by combining the aviation maintenance fields). We treat Basic Marines (newly enlisted Marines) as members of their eventual occupational field.[6]

The infantry, motor transport, and aircraft maintenance groups have risks for accidental deaths that are 32 percent to 57 percent higher than the Marines in the baseline occupational fields (appendix B provides details on baseline groups). These results are generally consistent with the picture presented in figure 10 that was based on fatality rates.

Location

Marines assigned to the more rural bases of the Southwest, South Carolina, and North Carolina have risks as much as 2.5 times higher

6. If an individual leaves the service with no specific occupational field listed in the quarterly records, we have (when possible) assigned them to fields based on training school attended.

than those at the baseline locations. The baseline for this comparison are locations other than those explicitly listed (Hawaii, Guam, Okinawa, and Pensacola are among the larger such locations). The urban San Diego and Norfolk area also have risks well above baseline levels. The results for Beaufort and Norfolk are higher than might have been expected based on fatality rates shown in figure 8. This is because we are capturing inherent geographical differences in risk, after controlling for differences that are due to characteristics (e.g., in boot camp) of the individuals located at these bases.

Warrant officers and junior enlisted have higher risk

The analysis covers only enlisted personnel. We include variables for various pay grade groups—E1 to E2, E3 to E4, E5 to E6—as well as warrant officers. Thus, the coefficients represent the difference in risk for these groups relative to senior personnel in grades E7 to E9. The coefficients indicate that junior enlisted (E1 to E2) personnel in their second 6 months of service face a risk more than twice as high as that for senior enlisted. The warrant officers also show a remarkably high risk—4 times greater than that for the senior enlisted, although the numbers of individuals and deaths involved here are small.

Early career has low risk followed by high risk

For the junior enlisted (E1 to E2), we explore their risks relative to time in service. Recruit training is a restrictive environment that limits the opportunities for individuals to engage in risky behavior. Not surprisingly, we find no risk of vehicle-related death during these first 12 weeks of service. On the other hand, the week after boot camp is a period of high risk (not quite at the level of statistical significance). This interval corresponds to a period of leave granted after boot camp. Another variable is used for the period 3 to 6 months after date of entry. This corresponds to a period of generally close supervision and limited freedom. We find that the risk of death is relatively low during this early period. Conversely, the second half of a Marine's first year is associated with much higher risk.

Reporting to a new command is associated with lower risk

We included variables to capture the risk associated with time relative to reporting to a new command, which we identified as entering a new present monitored command code (PMCC). We use one variable to cover the first 3 months at a new PMCC and another to cover the second 3 months. The first variable has a statistically significant coefficient of .38. This means that during the first 3 months at a new command, the risk of an accidental death is 38 percent of the risk facing people who have been at a command for more than 6 months. These variables are strongly correlated with the early career, because initial training is associated with frequent transfers among commands. But, the time-in-service variables should separately capture the low risk associated with that period of time.

Return from deployment increases risk

Individuals who have recently returned from deployment appear to be at higher risk of accidents than those who have not recently returned. The hazard rate for the first 3 months after deployment is not a statistically significant risk. However, the next 3 months show a 60 percent increase in the risk of death.

Promotions lower risk

Some events might trigger specific behaviors. We examined certain career events to determine what was associated with higher risk. We include a variable for the 3 months after an individual was promoted. The coefficient indicates that the risk is only 54 percent of that for people with the same demographics who did not get promoted. This reports the risk for those who were promoted as compared to other Marines of the same age, whether they were eligible for promotion or not. (We do not have sufficient data to evaluate the risk associated with not being promoted when eligible.) Our promotion variable depends on the date a promotion was effective, not the date on which the individual learns he or she will be promoted.

We also evaluated the effects of demotions. We examined the risk of individuals in the 3 months immediately after they are demoted and in the period between 3 and 6 months after demotion. The coefficients indicate no extra risk in the first 3 months, but over the next 3 months the risk of accidental death is increased (although not statistically significant).

Enlistment waivers are often associated with higher risk

Individuals with a history of drug use, traffic violations, or serious offenses require waivers to enter the USMC. Many of these factors are associated with some modest increase in risk.[7] Marines who entered with waivers for drug or alcohol issues have a statistically significant 26 percent higher risk.

Individuals with high and low AFQT scores have lower risk

We included variables for people whose education went beyond high school and those who did not have a full high school diploma. The coefficient on education beyond high school suggests a lower risk for this group relative to those with a high school diploma, but the coefficient is not significant. Differences in AFQT test scores are associated with differences in risk. Individuals with very low and very high scores have risks 20 to 30 percent below those in the middle ranges.

High and low physical fitness scores are associated with lower risk

We thought that physical fitness scores might be an indication of personal discipline or risk-taking behavior. We included variables for individuals with class 1 (high pass), class 2 (medium pass), and class 3 (low pass) scores. The coefficients on these are all significant. Individuals with these passing scores are less likely to be in a fatal vehicle accident than Marines who do not have a passing fitness score.

Temporary duty and marriage lower risk

An individual who is assigned temporary additional duty is at about 75 percent of the risk of a fatal vehicle accident as is an individual at his permanent duty station. An individual who was married within the year is at 60 percent of the risk faced at other times.

Seasonal effects

We included variables to represent the quarters of a calendar year. Our results indicate that fatalities are most likely to occur in the Jul–Sep quarter; the risk is 79 percent higher than in the Jan–Mar quar-

7. We caution against concluding that these results suggest changing recruitment policy. Large numbers of recruits enter under waivers and earlier CNA work has shown that they are often superior Marines [5, 6].

ter. The Apr–Jun and Oct–Dec quarters are also high-risk quarters. Fatal accidents are least likely to occur in the Jan–Mar quarter. An explanation may be that less travel takes place in the winter quarter.[8]

Combining risk factors

The above hazard rates provide information about how risk varies with a single characteristic. However, there might be interest in determining how risk changes with multiple characteristics. To estimate the relative risk between two people who differ by multiple characteristics, we must multiply the hazard rates. As an example, suppose we wanted to estimate the risk for a male E4 aviation mechanic as compared with a male E7 in one of the occupational fields not listed. (All other characteristics are assumed to be the same for the two individuals.) We can calculate the relative risk as

$$= \exp(\beta_{E3toE4}) * \exp(\beta_{AirMaint})$$
$$= 1.76 * 1.57$$
$$= 2.76$$

The hazard rates are drawn from table 3 (for convenience, pertinent lines from table 2 are repeated here). Notice that we did not have to include a value for "male" in the calculation above, because the comparison is between two males. We did not include other variables, because they too are assumed to be the same for both individuals. In this case, the combined risk is 2.76 times that of the reference individual.

Table 3. Selected estimation results from table 2

Variable	Hazard rate
E3 to E4	1.76
Aircraft maintenance & avionics	1.57
Male	2.47

8. Other seasonal factors related to the recruitment cycle (e.g., age mix, number of Marines) are already implicitly accounted for.

Estimating risks for motorcycle deaths

Because fatalities related to motorcycles now account for over 25 percent of vehicle-related deaths and the characteristics associated with these deaths seem to differ from those for other vehicles, we performed a separate analysis, which covers male personnel only—since no female Marines have died in motorcycle accidents. The estimation results are listed in table 4.

Table 4. Estimation results for the risk of motorcycle-related death

	Hazard rate [a]	p-value [b]
Location		
Lejeune / Cherry Point / New River	1.28	0.43
San Diego / Camp Pendleton	1.77	0.05 **
29 Palms / Barstow / Yuma	0.81	0.68
Beaufort / Parris Island	0.38	0.34
DC area (w/ Quantico)	1.14	0.81
Norfolk area	2.21	0.20
Occupational field		
Personnel and admin (01) & finance (34)	2.35	0.04 **
Aircraft maintenance & avionics (60–64)	1.93	0.08 *
Pilots (75) & aviation support (70, 72, 73)	1.91	0.31
Infantry, artillery, armor (03, 08, 18)	2.52	0.00 ***
Communications & data systems (06, 25, 40)	0.81	0.72
Engineers (13)	0.90	0.87
Motor transport (35)	1.57	0.33
Supply (30) & aviation logistics (66)	0.29	0.24
Race/ethnicity		
Hispanic	0.59	0.16
Black [c]	0.00	0.00 ***
Other non-White race	0.61	0.40
Physical fitness		
Physical fitness class 1 (high pass)	0.94	0.85
Physical fitness class 2 (med pass)	0.76	0.50
Physical fitness class 3 (low pass)	0.81	0.76
Pay grade / time in service		
E1 to E2 – 3 months or less since joining USMC	0.00	0.00 ***
E1 to E2 – 3 to 6 months since joining USMC	0.88	0.93
E1 to E2 – 6 months or more since joining USMC	1.28	0.77
E3 to E4	2.32	0.25
E5 to E6	3.43	0.07 *
Warrant officers	6.31	0.16

Table 4. Estimation results for the risk of motorcycle-related death (cont'd)

	Hazard rate [a]	p-value [b]
<u>Career events</u>		
3 months or less since reporting to command	0.37	0.03 **
3 to 6 months since reporting to command	0.81	0.54
Promoted within last 3 months	0.24	0.02 **
Demoted within last 3 months [c]	0.00	0.00
Demoted 3 to 6 months ago	3.57	0.09 *
Prior military legal action	1.42	0.73
0 to 3 months since deployment	1.43	0.36
3 to 6 months since deployment	1.61	0.21
6 to 9 months since deployment	0.67	0.50
Deployed [c]	0.00	0.00
6 months or less since reenlistment	1.61	0.33
6 to 12 months since reenlistment	1.14	0.80
<u>Miscellaneous demographics</u>		
Single with no dependents	0.93	0.80
Within a year after divorce [c]	0.00	0.00
Within a year after marriage	0.77	0.54
On temporary duty	0.74	0.35
Living on base	1.02	0.96
<u>Education and test scores</u>		
More than high school education	0.38	0.36
High school equivalency or less	0.33	0.27
AFQT score 1 to 40	0.78	0.42
AFQT score 85 to 99	0.62	0.27
<u>Enlistment waivers</u>		
Traffic waiver	1.37	0.58
Serious non-traffic waiver	1.48	0.39
Minor non-traffic waiver	0.81	0.77
Drug or alcohol waiver	1.45	0.07 *
Felony waiver	3.96	0.00 ***
<u>Time</u>		
Apr–Jun quarter	2.93	0.00 ***
Jul–Sep quarter	2.33	0.01 ***
Oct–Dec quarter	1.09	0.84
Quarterly time trend	1.03	0.01 ***

a. For categorical variables, hazard ratios are interpreted relative to the categories not listed (see appendix B for details).

b. *** significant at 1%, ** significant at 5%, * significant at 10%.

c. There were no motorcycle deaths during certain time periods (*Within a year after divorce, Demoted within 3 months*) or for some characteristics (*Black*). We retained the variables to maintain comparability with the all-vehicle model. Their estimated hazards are zero.

Key risk factors—results for motorcycles

In this section, we present results on key risk factors related to motorcycle fatalities.

Male and female

Because the motorcycle analysis covers males only, there are no hazard rates shown for gender. However, given that no females have been involved in fatal motorcycle accidents, it is fair to say that males are at higher risk.

Infantry, personnel, and aircraft maintenance are at highest risk

The infantry, personnel and administration, and aircraft maintenance groups have hazards as much as 2.5 times higher than baseline occupations. The personnel and administration group did not show significant hazard rates for overall vehicle accidents. The motor transport group (which was significant for overall vehicle risk) is not significant in this model of motorcycle deaths, even though their estimated hazard rate is moderately high. With the small numbers of motorcycle deaths, it is difficult to attain statistical significance.

Return from deployment is not significant

Whereas the effect of returning from deployment was quite strong in the model of all vehicle accidents, it is not significant for motorcycle deaths. Still, the estimates do show a 61-percent increase in risk for the second 3 months after deployment. In a later section, we explore whether the post-deployment risk might have increased in recent years with the growing numbers of motorcycle fatalities.

Felony and drug waivers are high risk

The risk of motorcycle death for those entering the USMC with a waiver for drug or alcohol offenses is 45-percent higher than for those who enter with no enlistment waiver. The risk for those who enter with a felony waiver is almost four times higher. Individuals with felony waivers (about 1.5 percent of Marines) account for a remarkable 7 percent of motorcycle deaths.

Risk is highest in the San Diego/Camp Pendleton area

Only the San Diego/Camp Pendleton area shows a significantly high risk for motorcycle fatalities, with a risk 77 percent higher than the baseline locations. The result is not surprising, as California weather is conducive to year-round motorcycle use and the urban setting increases likelihood of collision. The North Carolina bases show only a moderate risk for motorcycle deaths.

Earlier we saw (figure 9) that motorcycle fatality rates have begun to equalize between Camp Pendleton and Camp Lejeune. We will explore in the later section whether hazard rates for these locations are also changing over time.

The E5 to E6 pay grades have the highest risk

The E5 to E6 pay grades face the highest risk of a motorcycle fatality. The risk for Marines in these grades is three times higher than that for more senior enlisted personnel (E7–E9). As a group, the E5 to E6 pay grades account for just over a third of motorcycle deaths. Warrant officers also show a high hazard rate, but the value is not statistically significant and reflects just a single death.

Reenlistment is not associated with significantly higher risk

We wondered whether bonuses for reenlistment might be going toward the purchase of motorcycles and that this might help explain the high hazard rate for E5 to E6 pay grades. We do find a moderately high hazard rate in the first 6 months after reenlistment, but it is not a statistically significant risk.

Demotions increases risk while promotions reduce risk

The risk of motorcycle fatality is greatest in the period 3 to 6 month after demotion—almost four times higher than at other times. The risk of fatality is low in the 3 months immediately following promotion.

Time of year

The seasonal swings in motorcycle fatalities are more pronounced than for overall vehicle deaths. Peak risks occur in the spring and summer, with the risk of death three times higher in spring, as compared to the winter months.

The profile for motorcycle risk differs from that for automobiles

We found it interesting that two factors, highly significant for overall vehicle deaths, were not significant for motorcycle risk. Being single is not associated with increased risk of motorcycle fatality. The end for the first year of service is also not linked to any increase in risk. Motorcycle fatalities tend to be associated with older, more established Marines. It is a very different pattern of risk than we see for automobile deaths.

Changes in hazard rates over time

In this final section, we explore whether the relative risks have changed over time. In the graphical analysis, we saw some disturbing trends. Particularly troubling is the increase in motorcycle fatality rates among mid-level enlisted ranks. Other trends of concern are the increase in post-deployment fatalities, rising fatality rates among infantrymen, increasing motorcycle death rates for Marines at the North Carolina bases, and the overall increase in vehicle fatality rates at Camp Pendleton. We also saw some positive trends, with declining automobile deaths rates at some of the other bases.

We investigate those trends. Specifically, we explore how hazard rates have changed for the following variables:

- E5 to E6
- Infantry/artillery/armor
- Lejeune/Cherry Point/New River
- San Diego/Camp Pendleton
- 29 Palms/Barstow/Yuma
- 3 to 6 months since deployment
- 6 to 9 months since deployment
- 12 months or less since reenlistment

Whereas our earlier analyses gave us average hazard rates for the entire time period, we now estimate separate hazard rates for two intervals. We compare hazard rates in later years (FY 2003–FY 2007) to those in the earlier years (FY 1999–FY 2002). The split at FY 2003 corresponds roughly to the beginning of the build up for the Iraq war. The overall models are unchanged, except for the addition of variables to identify changes in hazard rates over time.

Estimation results are presented in table 5. We show hazard rates only for the variables of interest.[9] The first column gives the estimated hazard rate for the earlier time period; the second column gives the estimated hazard rate for the later years. The final column shows whether the difference between these hazard rates (over the two time periods) can be considered statistically significant. We also note the statistical significance of individual hazard rates, with marks next to the estimates in the hazard rate columns.

The table provides results from three models: one looks at all-vehicle deaths, another looks at motorcycle deaths, and the last considers the non-motorcycle (or automobile) deaths.

Results on how risks have changed

Hazard rates for the E5 to E6 pay grades have increased

The risk of vehicle death has increased for the E5–E6 pay grades since FY 2003. This increase is almost entirely related to motorcycles. Before FY 2003, the risk of a motorcycle fatality for the E5–E6 pay grades was almost indistinguishable from the baseline level facing more senior enlisted personnel. The risk has now risen dramatically to more than 5 times the baseline level.

Hazard rates for infantry/artillery/armor have increased

The risk of vehicle death has risen for the combat forces since FY 2003. The infantry have a risk of vehicle death that is now 66-percent higher than for the baseline occupational fields; their hazard rate was less than 1 before FY 2003. The higher risk seems to be associated with an increase in both automobile and motorcycle fatalities. Surprisingly, it is the increase in risk of automobile fatality that is statisti-

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9 Other coefficients change very little with the addition of the time period variables, and so are not reported again.

cally significant. The motorcycle hazard rate may have increased, but was already quite high before FY 2003. This is consistent with the trends in fatality rates seen in figure 11.

Table 5. Estimation results for the change in hazard rates over time

All vehicles

	Hazard rate (FY99–FY02)	Hazard rate (FY03–FY07)	Significant difference [a]
E5 to E6	0.95	1.74	**
Infantry/artillery/armor	0.90	1.66 ***	***
Lejeune / Cherry Pt / New River	1.99 ***	1.64 ***	
San Diego / Pendleton	1.61 **	1.75 ***	
29 Palms / Yuma / Barstow	2.84 ***	1.47	**
3 to 6 months since deployment	1.02	1.75 ***	
6 to 9 months since deployment	0.32	1.34	°
12 months or less since reenlistment	2.08 **	0.86	*

Motorcycles

	Hazard rate (FY99–FY02)	Hazard rate (FY03–FY07)	Significant difference
E5 to E6	1.24	4.92 **	**
Infantry/artillery/armor	2.09 *	2.69 ***	
Lejeune / Cherry Pt / New River	0.74	1.54	
San Diego / Pendleton	1.81	1.77 *	
29 Palms / Yuma / Barstow	0.44	1.02	
3 to 6 months since deployment	0.00 ***	1.83 *	***
6 to 9 months since deployment	0.00 ***	0.76	***
12 months or less since reenlistment	2.34	1.25	

Automobiles

	Hazard rate (FY99–FY02)	Hazard rate (FY03–FY07)	Significant difference
E5 to E6	0.95	1.13	
Infantry/artillery/armor	0.69	1.45 *	***
Lejeune / Cherry Pt / New River	2.40 ***	1.67 **	°
San Diego / Pendleton	1.52 *	1.79 ***	
29 Palms / Yuma / Barstow	3.54 ***	1.52	**
3 to 6 months since deployment	1.04	1.63 *	
6 to 9 months since deployment	0.44	1.83 **	°
12 months or less since reenlistment	1.91	0.55	*

a. *** significant at 1%, ** significant at 5%, * significant at 10%, ° significant at 20%. The final column indicates whether the change in hazard rates is statistically significant.

Lower automobile risks at Lejeune/Cherry Point/New River

The overall risk of vehicle death has perhaps declined at the North Carolina bases. The hazard rates from the all-vehicle model are statistically significant for each time period, with the value dropping from 1.97 to 1.60. That difference is not enough for us to confidently report a real decline. There has been a clear decline in the risk of automobile fatalities. There has also been an apparent increase in the risk of motorcycle death, but with the relatively small numbers of fatalities, we cannot say whether this change is meaningful.

Risks have remained relatively stable at San Diego/Camp Pendleton

The overall risk of vehicle death seems to have been relatively stable at the San Diego area bases, with perhaps a modest increase. This result is somewhat surprising given the increasing fatality rates we see in figure 9. Apparently the increase in fatalities is better explained by the characteristics of the individuals serving here, rather than being inherently related to the base or local conditions.

Significantly lower automobile risks at 29 Palms/Barstow/Yuma

The bases of the desert Southwest are a success story. They show a significant decline in the overall vehicle fatality hazard rates. The improvement comes from a lower risk of automobile fatality. The risk of motorcycle fatality may be increasing, but the hazard remains low.

Post-deployment risks are increasing

The risk of motorcycle deaths in the post-deployment period is increasing. Motorcycle hazard rates for the intervals 3 to 6 months and 6 to 9 months after deployment have both increased significantly. The hazard rate for the 3 to 6 months interval has become statistically significant in recent years (FY 2003–FY 2007). This confirms our expectations based on the worsening trends seen in figure 13. There also seems to have been an increase in risk of automobile deaths in the post-deployment period. The increase in automobile hazard rates for the interval 6 to 9 months after deployment comes very close to statistical significance.

Post-reenlistment risks have not increased

There is no indication of an increase in risks associated with reenlistment. In fact, the hazard rates for the post-reenlistment period seem to have declined. This suggests that the reenlistment bonuses offered in recent years are not a primary factor behind the increase in motorcycles fatalities.

Appendix A: Non-motorcycle results

Table 6. Estimation results for non-motorcycle vehicle deaths

	Hazard rate	p-value
Location		
Lejeune / Cherry Point / New River	1.97	0.00 ***
San Diego / Camp Pendleton	1.68	0.01 ***
29 Palms / Barstow / Yuma	2.39	0.00 ***
Beaufort / Parris Island	3.22	0.01 ***
DC area (w/ Quantico)	1.39	0.30
Norfolk area	2.04	0.08 *
Occupational field		
Personnel and admin (01) & finance (34)	0.73	0.28
Aircraft maintenance & avionics (60–64)	1.34	0.13
Pilots (75) & aviation support (70, 72, 73)	0.49	0.17
Infantry, artillery, armor (03, 08, 18)	1.06	0.75
Communications & data systems (06, 25, 40)	0.92	0.74
Engineers (13)	1.25	0.39
Motor transport (35)	1.43	0.11
Supply (30) & aviation logistics (66)	1.52	0.07 *
Race/ethnicity		
Hispanic	1.31	0.08 *
Black	1.34	0.54
Other non-White race	1.10	0.71
Physical fitness		
Physical fitness class 1 (high pass)	0.58	0.00 ***
Physical fitness class 2 (med pass)	0.63	0.02 **
Physical fitness class 3 (low pass)	0.33	0.00 ***
Pay grade / time in service		
E1 to E2 – in boot camp	0.00	0.00 ***
E1 to E2 – week after boot camp	3.91	0.08 *
E1 to E2 – 3 to 6 months since joining USMC	0.92	0.90
E1 to E2 – 6 months or more since joining USMC	3.57	0.03 **
E3 to E4	2.21	0.18
E5 to E6	1.04	0.95
Warrant officers	2.87	0.19
Career events		
3 months or less since reporting to command	0.37	0.00 ***
3 to 6 months since reporting to command	0.75	0.10 *
Promoted within last 3 months	0.57	0.00 ***
Demoted within last 3 months	0.91	0.83

Table 6. Estimation results for non-motorcycle vehicle deaths (cont'd)

	Hazard rate	p-value
Career events (cont'd)		
Demoted 3 to 6 months ago	1.23	0.63
Prior military legal action	1.30	0.62
0 to 3 months since deployment	0.70	0.26
3 to 6 months since deployment	1.48	0.12
6 to 9 months since deployment	1.46	0.18
Deployed [c]	0.00	0.00
6 months or less since reenlistment	0.67	0.49
6 to 12 months since reenlistment	1.44	0.40
Miscellaneous demographics		
Male	1.74	0.15
Female, age 19–20	1.99	0.19
Single with no dependents	1.50	0.02 **
Within a year since divorce	0.51	0.50
Within a year since marriage	0.53	0.05 **
On temporary duty	0.79	0.21
Living onbase	1.09	0.67
Education and test scores		
More than high school education	0.47	0.29
High school equivalency or less	1.01	0.97
AFQT score 1 to 40	0.82	0.20
AFQT score 85 to 99	0.74	0.18
Enlistment waivers		
Traffic waiver	1.06	0.88
Serious non-traffic waiver	0.92	0.78
Minor non-traffic waiver	1.40	0.41
Drug or alcohol waiver	1.21	0.12
Felony waiver	0.65	0.40
Time		
Apr–Jun quarter	1.38	0.08 *
Jul–Sep quarter	1.73	0.00 ***
Oct–Dec quarter	1.95	0.00 ***
Quarterly time trend	1.00	0.74

a. ***significant at 1%, ** significant at 5%, * significant at 10%.

b. For categorical variable, hazard ratios are interpreted relative other categories not listed.

Appendix B: List of categorical variables and their baselines

Table 7. List of categorical variables and their baselines

Variables	Baseline
<u>Location</u>	
Lejeune/Cherry Point/New River San Diego/ Camp Pendleton 29 Palms/Barstow/Yuma Beaufort/Parris Island DC area (w/ Quantico) Norfolk area	All other locations: e.g., Hawaii, Pensacola, Guam, Okinawa, Albany, New Orleans
<u>Occupational field</u>	
Personnel and admin (01) & finance (34) Aircraft maintenance & avionics (60–64) Pilots (75) & aviation support (70, 72, 73) Infantry, artillery, armor (03, 08, 18) Communications & data systems (06, 25, 40) Engineers (13) Motor transport (35) Supply (30) & aviation logistics (66)	All other occupational fields: e.g., Intelligence (02), Logistics (04), Utilities (11), Ground ordnance maintenance (21), Signals (26), Food service (33), Military police (58), Aviation ordnance (65)
<u>Race/ethnicity</u>	
Hispanic; Black; other non-white race	White
<u>Physical fitness</u>	
Physical fitness class 1; physical fitness class 2; physical fitness class 3	Failing, excused, or missing physical fitness scores
<u>Pay grade / time in service</u>	
E1 to E2 (in boot camp); E1 to E2 (week after boot camp); E1 to E2 (3 to 6 months since joining); E1 to E2 (6 months or more since joining); E3 to E4; E5 to E6; warrant officers	E7 to E9
<u>Career events—new command</u>	
3 months or less since reporting to command 3 to 6 months since reporting to command	Other months
<u>Career events—demotion/promotion</u>	
Promoted within last 3 months Demoted within last 3 months Demoted 3 to 6 months ago	Other months

Table 7. List of categorical variables and the baselines (cont'd)

Variables	Baseline
Career events—months since deployment	
0 to 3 months since deployment	Other months
3 to 6 months since deployment	
6 to 9 months since deployment	
Career events—reenlistment	
6 months or less since reenlistment	Other months
6 to 12 months since reenlistment	
Career events—deployment	
Deployed	Not deployed
Education and test scores	
More than high school; high school equivalency	High school degree
AFQT score 1 to 40; AFQT score 85 to 99	AFQT score 41 to 84 or missing
Miscellaneous demographics	
Male; female, age 19–20	Other females (age 17–18, over 20)
Single with no dependents	Married, or with dependents
Within a year since divorce	Other months
Within a year since marriage	Other months
On temporary duty	Not on temporary duty
Living on base	Living off base
Enlistment waivers	
Traffic waivers; serious non-traffic waivers; minor non-traffic waivers; drug or alcohol waivers; felony waivers	No enlistment waivers
Time of year	
Apr–Jun quarter; Jul–Sep quarter; Oct–Dec quarter	Jan–Mar quarter

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