Effects of Vehicle Power on Passenger Vehicle Speeds

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ABSTRACT

Objectives: During the past two decades, there have been large increases in mean horsepower and the mean horsepower-to-vehicle-weight ratio for all types of new passenger vehicles. This study examined the relationship between travel speeds and vehicle power, defined as horsepower per 100 pounds of vehicle weight.

Methods: Speed cameras measured travel speeds and photographed license plates and the faces of drivers of passenger vehicles traveling on roadways in northern Virginia during daytime off-peak hours in spring 2013. The driver licensing agencies in the District of Columbia, Maryland, and Virginia provided vehicle information numbers (VINs) by matching license plate numbers with vehicle registration records and provided the age, gender, and zip code of the registered owner(s). VINs were decoded to obtain the curb weight and horsepower of vehicles. The study focused on 26,659 observed vehicles for which information on horsepower was available and the observed age and gender of drivers matched vehicle registration records. Log-linear regression estimated the effects of vehicle power on mean travel speeds, and logistic regression estimated the effects of vehicle power on the likelihood of a vehicle traveling over the speed limit and more than 10 mph over the limit.

Results: After controlling for driver characteristics, speed limit, vehicle type, and traffic volume, a 1-unit increase in vehicle power was associated with a 0.7% increase in mean speed, a 2.7% increase in the likelihood of a vehicle exceeding the speed limit by any amount, and an 11.6% increase in the likelihood of a vehicle exceeding the limit by 10 mph. All of these increases were highly significant. To illustrate the findings, a 3-unit increase in vehicle power, which is equivalent to the difference between the 10th and 90th percentile vehicle power for the study vehicles, is associated with a 38% increase in the likelihood that a vehicle exceeds the speed limit by more than 10 mph.

Conclusions: Speeding persists as a major factor in crashes in the United States. There are indications that travel speeds have increased in recent years. The current findings suggest that the trend toward substantially more powerful vehicles is contributing to higher speeds. Given the strong association between travel speed and crash risk and crash severity, this is cause for concern.

Keywords: Vehicle horsepower, Vehicle power, Vehicle speeds, Speeding

INTRODUCTION

In the United States, as in other highly motorized countries, speeding persists as an important factor in crashes. Higher speeds are associated with both the risk of crashing and the severity of injuries that occur (Elvik, 2005). About one-third of crash deaths in the United States involve at least one driver who was issued a traffic citation for speeding or coded as traveling too fast for conditions, exceeding the speed limit, or racing (Insurance Institute for Highway Safety (IIHS), 2016). The National Highway Traffic Safety Administration estimates that crashes involving a speeding vehicle cost the nation $52 billion in 2010, an average of $168 for every person in the United States (Blincoe et al., 2015).

National observational surveys of traffic speeds conducted in 2007 and 2009 found that many drivers exceeded posted speed limits on all kinds of roads and that the problem worsened from 2007 to 2009 on freeways and expressways (Huey et al., 2012). For example, the proportion of vehicles on limited-access roads that were exceeding speed limits increased from 48% to 72%, and the proportion that were exceeding speed limits by more than 10 mph increased from 10% to 14%.

Studies using a variety of methods have identified a number of characteristics of drivers who speed. When compared with non-speeders, speeders more often were younger (Preusser et al., 1988; Richard et al., 2012; Schroeder et al., 2013; Williams et al., 2006) and male (Campbell et al., 2013; Preusser et al., 1988; Richard et al., 2012), and they had more violations and crashes on their driving records (Williams et al., 2006). Young drivers were more likely than older drivers to have prior speeding citations (Janke et al., 2003; Shroeder et al., 2013). In a study that monitored vehicle speeds and road network data during 3-4 weeks of more than 160 drivers in their own vehicles, driving a pickup truck or sports car compared with a sedan, minivan, or SUV was moderately associated with lower odds of speeding in Seattle but was associated with higher odds of speeding in Texas (Richard et al., 2012).

An analysis of the trends and characteristics of speeding-related fatal crashes found a wide variety of factors related to speeding including, for example, roadway type (arterials vs. other roadway types) and characteristics (curved vs. straight road), driver characteristics (young vs. older, male vs. female, alcohol-impaired vs. sober), and rural vs. urban environments (Liu et al., 2005). The study found that vehicle type also was related to speeding. Motorcycle operators were much more likely than drivers of passenger vehicles or large trucks to be speeding. Drivers of cars, SUVs, and pickups were speeding at similar rates, which were much higher than the rates for drivers of vans and large trucks.

Some research suggests that posted speed limits influence not only travel speeds but also the extent of speeding. A study of travel speeds in Western Australia found that drivers exceeded the speed limits by wider margins as speed limits increased (Giles, 2004).

One likely factor influencing travel speeds in the United States is a recent trend toward higher maximum speed limits on freeways and interstates. In a study of the effects of increases in states' maximum speed limits over the past two decades, Farmer (2016) found that each 5 mph increase in the maximum state speed limit resulted in an 8% increase in fatality rates on interstates and freeways and a 4% increase in fatality rates on other roads.

Another trend likely affecting travel speeds is increasingly powerful vehicles. From vehicle model year 1985 to model year 2015, mean horsepower increased by 98% for SUVs (from 124 to 246 horsepower), 83% for cars (from 113 to 206 horsepower), and 168% for pickups (from 129 to 345 horsepower) (Highway Loss Data Institute (HLDI), 2015). The mean curb weight of vehicles also increased from model year 1985 to model year 2014 but at a slower pace; the increase in curb weight was 19% for SUVs (from 3,432 to 4,097 pounds), 14% for cars (from 2,717 to 3,105 pounds), and 63% for pickups (from 3,217 to 5,231 pounds). Horsepower typically is standardized to vehicle weight because the heavier the vehicle, the more horsepower is needed to achieve a given level of acceleration or top speed. For the remainder of this paper the term "vehicle power" will be defined as horsepower per 100 pounds of vehicle weight. As shown in Figure 1, mean vehicle power increased from model year 1985 to model year 2015 by 66% for SUVs (from 3.6 to 6.0), 60% for cars (from 4.1 to 6.6), and 65% for pickups (from 4.0 to 6.6).

There has been little research looking at the effects of vehicle power on crash risk. A series of studies by HLDI (1995, 2004, 2007) found that vehicle power was strongly associated with insurance claim losses. The most recent report, published in 2007, was based on 2003-05 model four-door cars. It found that increases in vehicle power were associated with higher average losses per insured vehicle year for all motor vehicle insurance crash coverages after controlling for vehicle price and other covariates such as rated driver age, gender, and marital status. The overall loss estimates combine the effects of horsepower on claim frequency (number of claims per insured vehicle year) and on the severity of claims (average loss payment per claim). For most insurance coverages, horsepower had a significant effect on both claim frequency and claim severity. For example, an additional 1 unit of vehicle power was associated with an estimated 5.2% increase in losses under collision coverage per insured vehicle year (an insured vehicle year is one vehicle insured for 1 year, two vehicles insured for 6 months each, etc.) for rated drivers ages 25-64; the estimated 5.2% increase in losses combines a 2.8% increase in claim frequency with a 2.4% increase in claim severity. Collision coverage insures against physical damage to a driver's vehicle sustained in a crash when the driver is at fault. Among most coverages, losses associated with increases in vehicle power among 16-24-year-old drivers were even greater.

Although it makes sense that higher vehicle power would translate into higher travel speeds, no prior research on this topic could be found. The current field study examines the association between vehicle power and observed passenger vehicle travel speeds, after accounting for other potential predictors of vehicle speed, and whether the effects of vehicle power differ by driver characteristics and speed limits.

METHOD

Travel speeds and photos of drivers and license plates were collected with roadside photo radar cameras, and information on horsepower and vehicle weight came from vehicle identification numbers (VINs) obtained by matching license plate numbers with vehicle registration records.

Data Collection

During April-May 2013, off-peak travel speeds of passenger vehicles were measured at 10 sites on heavily traveled roadways in northern Virginia, with speed limits ranging from 40 to 65 mph. To minimize the effects of roadway geometric characteristics, the sites were located away from intersections and ramps on flat, straight roadway segments. Counts of passing vehicles and speeds were collected via photo radar cameras deployed on the right roadway shoulder by Brekford Corporation. To minimize motorists' awareness of cameras, the camera was encased in a metal cabinet disguised as a traffic cone and its flash unit was deactivated.

At each site, traffic traveling in both directions was observed during 10 a.m.-3 p.m. on a weekday when it was not raining. There were at least two lanes of traffic in each direction at each site, and the cameras measured the speeds of more than 90% of passing vehicles in all lanes. For each vehicle for which the travel speed was recorded, a photograph was taken of the front of the vehicle to capture the license plate and the driver.

Experienced camera technicians at Brekford Corporation transcribed the license plate numbers from the photographs and coded the driver gender and age categories (younger than 20, 20-29, 30-39, 40-64, 65 and older) when these were clearly discernible. The study included only the 85,794 passenger vehicles that were registered in Virginia, Maryland, or the District of Columbia and had valid speed measurements and discernible license plate numbers. A researcher reviewed the license plate numbers of a randomly selected sample of 10% of the 85,794 vehicle photographs and found that more than 98% of the license plate numbers were transcribed correctly by the technicians. The technicians could identify driver gender and estimated age category for 58,920 (69%) of the 85,794 vehicles.

Electronic files of the license plate numbers for the 85,794 vehicles with valid speed measurements and discernible license plate numbers were provided to the Virginia, Maryland, and District of Columbia vehicle licensing agencies. The agencies matched 61,007 (71%) of the plate numbers with vehicle registration records and provided researchers with the VINs and the age, gender, and zip code of residence of the registered owner(s) for these vehicles.

The age and gender of drivers coded from the photographs were compared with the age and gender of the registered owners. When the gender and age group (± 10 years) coded from the photographs matched those of one of the registered owners, it was considered a match and the age, gender, and zip code information from the registration record was used. It can be difficult to estimate the age group of a driver from a photograph, and using a 10-year age buffer reduced the possibility of excluding records that should have been included because technicians had inaccurately estimated a driver's age. There were 27,645 records for which a registered owner was considered to be the driver (45% of the 61,007 records received from the driver licensing agencies).

VINs were decoded to determine the make, series, model, and model year of vehicles, and the associated curb weight and horsepower were obtained from vehicle information databases maintained by HLDI. Vehicles were classified into the following types based on HLDI definitions: non-sports cars, sports cars, minivans, cargo or large passenger vans, pickups, and SUVs. In models examining the effects of vehicle power and other factors on vehicle speeds, small sample sizes necessitated combining sports cars with other cars and cargo/large passenger vans with minivans. Pickups and SUVs also were combined as they had similar vehicle speed and vehicle power profiles.

Socioeconomic information about the drivers' zip code of residence was obtained from the U.S. Census Bureau (2014). The percentage of residents age 25 and older with a bachelor's degree or post-bachelor work in 2013 in each zip code was used in the analyses.

Information on curb weight, horsepower, or education status of a driver's zip code of residence was unavailable for 986 of the 27,645 vehicles for which a registered owner was considered to be the driver, and these were excluded from the study, yielding a final data set of 26,659 observations.

Analyses

Models were developed to examine the influence of horsepower and other variables on mean vehicle speeds, the likelihood of vehicles exceeding the posted speed limit by any amount, and the likelihood of vehicles exceeding the posted speed limit by more than 10 mph. Initial models included the following independent variables: vehicle power, vehicle counts per hour per lane (per 100 vehicles), and indicators for driver age (age 29 and younger vs. age 30 and older), driver gender (male vs. female), driver zip code education status (less than 50% of residents age 25 and older with at least a bachelor's degree vs. more than 50%; no zip codes had exactly 50% of residents with a bachelor's degree), speed limit (50 and 55 mph vs. 40 and 45 mph, 60 and 65 mph vs. 40 and 45 mph), and vehicle type (pickups and SUVs vs. cars, minivans and larger vans vs. cars). The initial models also included interactions between vehicle power and all of the indicator variables. In the final models presented below, the main effects of all independent variables were included. Interaction terms were included in a model only if they were significant ($p<0.05$).

Model for mean vehicle speeds: A log-linear regression model was used to estimate the effects of vehicle power on mean vehicle speeds. The dependent variable was the natural logarithm of speed. Based on the log-linear regression analysis, the estimated effect of vehicle power depends on the covariates that interact with vehicle power (speed limit and driver zip code education status). An overall effect of vehicle power (including the main effect of vehicle power and the interaction effects of vehicle power with speed limit and zip code education status) was estimated assuming the distribution of these covariates was the same as that for all of the drivers and speed limits included in the analysis. The following was derived for each combination of the covariates: the mean speed after a 1-unit vehicle power increase divided by the mean speed without the power increase. Then the estimated overall effect of a 1-unit vehicle power increase was the weighted geometric mean of the speed ratios, with the weights equal to the proportion of observations in each combination. Similarly, an overall effect was derived for a 3-unit vehicle power increase (i.e., a change equivalent to a 90 horsepower increase in a 3,000-pound vehicle); this represents the difference in vehicle power between the 10th and 90th percentile vehicle power considering all of the vehicles in the study.

The overall effects of vehicle power on roads with different speed limits (including the main effect of vehicle power and the interaction effects of vehicle power with zip code education status) also were estimated, by assuming that the distribution of the driver zip code education status covariate was the same on roads with different speed limits. For each speed limit category, the following was derived for each category of driver zip code education status: the mean speed after a 1-unit vehicle power increase divided by the mean speed without the power increase. Then the estimated overall effect was the weighted geometric mean of the speed ratios, with the weights equal to the proportion of observations in each category of the driver zip code education status.

Models for proportion of vehicles that were speeding: Separate logistic regression analyses evaluated the effects of vehicle power on the likelihood that a vehicle exceeded the speed limit by any amount and the likelihood that a vehicle exceeded the speed limit by more than 10 mph. The dependent variable was a binary speed indicator (exceeded speed limit or not, traveling more than 10 mph over the speed limit or not). None of the interaction terms was significant in the model predicting the likelihood of a vehicle exceeding the speed limit by any amount, so the estimated overall effect of vehicle power was equivalent to the estimated main effect. For the model predicting the likelihood of a vehicle traveling more than 10 mph over the speed limit, there was a significant interaction between vehicle power and driver zip code education status. Thus, the estimated overall effect of vehicle power (including the main effect of vehicle power and the interaction effect of vehicle power and driver zip code education status) on the odds that a vehicle was exceeding the speed limit by more than 10 mph was equal to the weighted geometric mean of the odds ratios associated with a 1-unit increase in vehicle power for each category of the driver zip code education status covariate, with the weights equal to the proportion of observations in each category.

The odds ratios derived from the logistic regression models were transformed into estimates of relative risk because the odds ratios are not good approximations for relative risk ratios when the incidence of the outcome of interest is not rare in the study population (i.e., greater than 10%), as was the case for exceeding the speed limit by any amount at all observation sites and exceeding the speed limit by more than 10 mph at four of the 10 sites. All odds ratios (ORs) were transformed into relative risks (RRs) as $RR=OR/[(1-P_0)+(P_0\times OR)]$ (Zhang and Yu, 1998). For relative risks associated with categorical variables, P_0 was equal to the proportion of vehicles exceeding the speed limit by any amount or exceeding it by more than 10 mph among observations in the baseline condition. For relative risks associated with continuous variables, P_0 was equal to the overall proportion of vehicles exceeding the speed limit by any amount or by more than 10 mph.

For example, in the logistic regression model of vehicles exceeding speed limits by more than 10 mph, if the estimate for the driver zip code education status indicator is -0.4885, the odds ratio is 0.6135 (i.e., exp(-0.4885)) when comparing the odds of exceeding speed limits by more than 10 mph among drivers in lower education status zip codes with the odds among drivers in higher education status zip codes. With 12.3% of vehicles with drivers in higher education status zip codes exceeding the speed limit by more than 10 mph (P_0), the relative risk is 0.6442 (i.e., $0.6135/[(1–0.123)+(0.123\times 0.6135)]$). In other words, a driver living in a lower education status zip code was 35.6% less likely to exceed the speed limit by more than 10 mph than a driver living in a higher education status zip code. In the same model, if the estimate for overall effect of vehicle power is 0.1259, the odds ratio associated with a 1-unit increase in vehicle power is 1.13 (i.e., exp(0.1259)). With 12.0% of observed vehicles exceeding the speed limit by more than 10 mph (P_0), the relative risk is 1.12 (i.e., $1.13/[(1–0.120)+ (0.120\times 1.13)]$). In other words, a 1-unit increase in vehicle power is associated with a 12% increase in the likelihood that a driver exceeded the speed limit by more than 10 mph.

RESULTS

Table 1 shows the vehicle counts, speed limit, number of lanes in each direction, hourly traffic counts per lane, characteristics of observed passenger vehicle drivers, and the measures of vehicle speed and vehicle power for each of the 10 observation sites and for the sites combined. Hourly traffic counts per lane ranged from 306 to 753 vehicles and averaged 534 vehicles. About two-thirds (66.5%) of the drivers observed were male, 9.8% were age 29 or younger, and 51.8% lived in zip codes where less than half of adult residents had a bachelor's degree or higher education. The mean travel speed across sites was 54.1 mph; mean speeds were higher at sites with higher speed limits. Overall, 69.5% of vehicles were exceeding the speed limit by any amount (range 37.3%-89.9%), and 12.0% were exceeding it by more than 10 mph (range 2%-27%). Among all observed vehicles, horsepower ranged from 49 to 650 and vehicle power ranged from 2.5 to 16.9 horsepower per 100-pound weight. Mean horsepower was 204.1, and mean vehicle power was 5.5; these measures varied slightly across sites. As noted above, the difference between the 10th and 90th percentile vehicle power was 3 horsepower per 100-pound weight.

Table 2 summarizes vehicle speeds and vehicle power by driver characteristics, speed limit, and vehicle type. Mean speeds were about 2 mph higher for drivers age 29 and younger than for drivers age 30 and older and for drivers living in zip codes with lower education status than for drivers living in other zip codes, and were about 1 mph higher for male drivers than for female drivers. The percentages of drivers exceeding the speed limit by any amount and by more than 10 mph were higher among drivers age 29 and younger than among drivers age 30 and older, but smaller differences were observed by gender or the education status of the driver's zip code. Mean speeds increased as speed limits increased. The percentages of drivers exceeding the speed limit by any amount and by more than 10 mph were substantially higher on roads with speed limits of 50-55 and 60-65 mph than on roads with speed limits of 40-45 mph and were similar for speed limits of 50-55 mph and 60-65 mph. There were minimal differences in vehicle power by speed limit or driver characteristics.

With regard to vehicle type, mean speeds ranged from 51.5 mph for cargo and large passenger vans to 56 for sports cars and 56.3 for pickups. Cargo and large passenger vans also were least likely to be exceeding the speed limit by any amount (59.7%) or by more than 10 mph (5.2%), while sports cars were most likely to be speeding (76.6%) or speeding by more than 10 mph (17%). Vehicle power, defined as mean horsepower per 100-pound vehicle weight, ranged from 4.6 for cargo and large passenger vans to 7.7 for sports cars. As noted above, in subsequent analyses sports cars were combined with other cars, and cargo/large passenger vans were combined with minivans due to small samples of sports cars and cargo/large passenger vans. SUVs and pickups also were combined due to their similar profiles of travel speeds and vehicle power.

Mean Vehicle Speeds

Table 3 provides results of the log-linear regression model of the effects of vehicle power and other predictors on mean vehicle speed. After accounting for the effects of other predictors, mean speed did not vary significantly by driver gender. The mean speed of drivers age 29 and younger was 1.9% higher than the mean speed of drivers age 30 and older. An increase of 100 vehicles per hour per travel lane reduced the mean speed by 1.2%. Compared with sites with speed limits of 40-45 mph, the mean speed was 37.6% higher at sites with speed limits of 50-55 mph and 59.4% higher at sites with speed limits of 60-65 mph. All of these differences were significant. Compared with the mean speed of cars, the mean speed of minivans and cargo/large vans was 1% lower, a significant difference; mean speeds of cars and pickups/SUVs did not differ significantly.

An increase in vehicle power was associated with a significant increase in mean vehicle speed, and the effect differed significantly by the education status of the driver's zip code and speed limit. Higher vehicle power was associated with a smaller increase in mean speeds for roads with 50-55 mph or 60-65 mph speed limits compared with roads with 40-45 mph limits, and a larger increase in mean speeds for drivers in lower education zip codes compared with drivers in higher education zip codes.

Likelihood that Vehicles Were Speeding

Table 4 summarizes results of the logistic regression model of the effects of vehicle power and other predictors on the likelihood that a vehicle exceeded the speed limit by any amount. After accounting for the effects of other predictors, the likelihood of a vehicle speeding was 5.8% higher for drivers age 29 and younger compared with drivers 30 and older and, 1.9% higher for drivers living in lower education status zip codes compared with drivers in higher education status areas. Compared with sites with speed limits of 40-45 mph, the likelihood of a vehicle speeding was 71.8% higher at sites with speed limits of 50-55 mph and 72.3% higher at sites with speed limits of 60-65 mph. An increase of 100 vehicles per hour per lane was associated with a 1.6% increase in the likelihood of speeding. All of these differences were significant. The likelihood of speeding did not vary significantly by vehicle type or by driver gender.

Table 5 summarizes the results of the model for the likelihood of a driver exceeding the speed limit by more than 10 mph. All of the main effects were significant except the indicator for pickups and SUVs compared with cars. The likelihood of speeding by more than 10 mph was 9.7% higher for male drivers compared with female drivers, 37.3% higher for drivers age 29 and younger compared with drivers age 30 and older, 35.6% lower for drivers living in lower education zip codes compared with drivers in other areas, and 32.1% lower for minivans and cargo/large vans compared with cars. Compared with roads with 40-45 mph speed limits, the likelihood of speeding was 361% higher on roads with 50-55 mph speed limits and 459.7% higher on roads with 60-65 mph speed limits. An increase of 100 vehicles per hour per lane was associated with a 19.1% increase in the likelihood of speeding by more than 10 mph.

An increase in vehicle power was associated with an increase in the likelihood of a vehicle speeding by more than 10 mph. The increased likelihood was significantly larger for drivers residing in lower education status zip codes compared with other zip codes.

Overall Effects of Vehicle Power on Speeds

As shown in Table 6, after controlling for main effects and the effects of covariate interactions with vehicle power, a 1-unit increase in vehicle power was associated with a 0.7% increase in mean vehicle speed, and a 3-unit increase in vehicle power was associated with a 2.2 increase. Table 6 also presents the effects of vehicle power on mean speeds for roads with different speed limits. For example, after controlling for main effects and the interactions of vehicle power and driver zip code education status, each 3-unit increase in vehicle power was associated with increases in mean speeds of 2.9% on roads with 40-45 mph speed limits, 1.9% on roads with 50-55 mph speed limits, and 1.7% on roads with 60-65 mph speed limits.

After controlling for other predictors, with 69.5% of all study vehicles exceeding the speed limit, a 1-unit increase in vehicle power was associated with a 2.7% increase in the likelihood that a driver was speeding, and 3-unit increase in vehicle power was associated with a 7.7% increase in likelihood.

After controlling for covariates and the effects of the interaction of vehicle power and education status of driver zip code and with 12% of all study vehicles exceeding the speed limit by more than 10 mph, a 1-unit increase in vehicle power was associated with a 11.6% increase in the likelihood that a driver was exceeding the speed limit by more than 10 mph. A 3-unit increase in vehicle power was associated with a 38.3% increase in the likelihood of a driver speeding by more than 10 mph.

Illustration of Effects of Increase in Vehicle Power on Speed

Several exemplar vehicles with varying performance capabilities were used to illustrate the association of vehicle power with vehicle speed. Table 7 shows the estimated percentage increases in mean vehicle speeds and the likelihood that a vehicle exceeds the speed limit by any amount or by more than 10 mph for vehicles with vehicle power (i.e., horsepower per 100-pound vehicle weight) of 5.7 (e.g., 2015 Honda Accord with 4-cylinder engine), 7.8 (e.g., 2015 Honda Accord with 6-cylinder engine), and 15.9 (e.g., Dodge Challenger SRT Hellcat), relative to a vehicle with vehicle power of 3.3 (e.g., 1981 Honda Accord).

A comparison of the 1981 Accord and the base model 2015 Accord illustrates the effects on travel speeds of increasing vehicle power in a mainstream popular sedan. The 1981 Accord, with a 4-cylinder engine, has 75 horsepower and a curb weight of 2,249 pounds, yielding vehicle power of 3.3 horsepower per 100-pounds of vehicle weight. In contrast, the 2015 Accord base model, also with a 4-cylinder engine, has 185 horsepower and a curb weight of 3,254 pounds, or vehicle power of 5.7. After accounting for other factors and relative to a vehicle with the performance specifications of the 1981 Honda, a vehicle with the performance specifications of the 2015 basic Accord would travel an estimated 1.7% faster, on average, and have a 6.1% higher likelihood of speeding and a 29.1% higher likelihood of speeding by more than 10 mph.

The 6-cylinder engine version of the 2015 Honda Accord has 278 horsepower and a curb weight of 3,554 pounds, or vehicle power of 7.8. Relative to a vehicle with the power of the 1981 Honda, it is estimated that a vehicle with the power of the 2015 6-cylinder Accord would travel 3.3% faster, on average, and have a 11.2% higher likelihood of speeding and a 61.3% higher likelihood of speeding by more than 10 mph.

Finally, an example of a vehicle with extreme power is the 2015 Dodge Challenger SRT Hellcat. The Hellcat has 707 horsepower and a curb weight of 4,439 pounds for a vehicle power of 15.9. Based on the sample of vehicles in the current study, after controlling for other factors influencing travel speeds, and relative to a vehicle with the power of a 1981 Honda, it is estimated that a vehicle with the power of the 2015 Hellcat would travel 9.6% faster, on average, and have a 25.9% higher likelihood of speeding and a 233.1% higher likelihood of speeding by more than 10 mph.

DISCUSSION

Speeding is a persistent and important factor in crashes in the United States. Recently there has been a trend toward higher speed limits on freeways and interstates, and national surveys indicate that vehicles exceeding posted speed limits on freeways and expressways increased substantially from 2007 to 2009 (Huey et al., 2012). The link between higher speed limits and faster vehicle speeds and increases in traffic fatalities in the United States is well-established (Farmer, 2015; Friedman et al., 2009; Patterson et al., 2002; Retting and Cheung, 2008; Retting and

Teoh, 2008). However, there has been little scrutiny directed at the potential contribution of higher vehicle power to higher vehicle speeds, even though mean horsepower and mean vehicle power, defined as the horsepower-to-vehicle-weight ratio, in new passenger vehicles increased dramatically from the mid-1980s to the present.

Prior research found that vehicle power was strongly associated with higher insurance losses (HLDI, 1995, 2004, 2007). The current study is the first known research to examine the association between vehicle power and travel speeds. Results indicate that after controlling for driver characteristics, speed limits, vehicle type, and traffic flow, an increase in vehicle power was associated with an increase in mean vehicle speed and the likelihood that a vehicle was exceeding the speed limit by any amount or by more than 10 mph. An example using the Honda Accord illustrated the substantial increase in vehicle power over the last 25 years even in mainstream popular sedans and the substantial effects of this increased power on travel speeds. Based on the vehicles in the current study, the study findings indicate that vehicles with the 90th percentile vehicle power are 38% more likely to exceed the speed limit by 10 mph relative to vehicles with the 10th percentile vehicle power.

In the current study, the effects of vehicle power on vehicle speeds did not vary significantly by driver gender or age after controlling for other factors, including vehicle type. This suggests that the idea that high-horsepower vehicles are risky only for young drivers or male drivers is incorrect, but also should be considered within the context that drivers age 29 and younger were traveling faster than drivers 30 and older to begin with, based on all three measures of vehicle speed, and men were significantly more likely than women to be speeding by more than 10 mph. After accounting for driver characteristics and other factors, the effects of vehicle power also did not vary by vehicle type. However, the sample sizes for the vehicle type with the lowest mean vehicle power, cargo and large vans, and the vehicle type with the highest mean vehicle power, sports cars, were too small to be examined separately from other vans and cars, respectively. It is unclear why the effects of horsepower were greater for drivers living in lower education status area compared with other drivers.

Speed limits had a strong effect on travel speeds, such that higher speed limits were associated with higher mean speeds and with an increased likelihood of exceeding the speed limit and exceeding it by more than 10 mph. The effects of vehicle power on mean speeds varied by speed limit such that the effect size declined with speed limit. For example, a 3-unit increase in vehicle power was associated with increases of 2.9%, 1.9%, and 1.7% on roads with 40-45, 50-55, and 60-65 mph, respectively. These differences are small but meaningful differences in overall speeds. Although the percentage change in mean speed declined slightly as speed limits increased, the effects translate into comparable increases in actual speeds traveled.

In the current analysis, more than half of the vehicle records with valid speed measurements and vehicle power information were excluded due to missing information on driver characteristics. Records were excluded when the driver age or gender was not discernible from the photographs, the driver age or gender did not match the driver age and gender of the registered owner(s) on the state registration records, the age and gender of the owner(s) on the registration record was missing, or the education status of the zip code of the driver's residence was not available from the U.S. Census. Similar analyses were conducted using all of the vehicle records with valid speed measurements and vehicle power information. The independent variables were vehicle power, speed limit indicators, and vehicle counts per hour per lane (per 100 vehicles). The analyses found that a 1-unit increase of vehicle power was associated with a 0.7% increase in mean vehicle speed, a 2.8% increase in the likelihood that a driver was exceeding the speed limit by any amount, and an 11.5% increase in the likelihood of a driver exceeding the speed limit by more than 10 mph. All of these increases were significant and consistent with results from the models including the driver characteristics and vehicle types.

Speeds were measured in urbanized areas in Northern Virginia in free-flowing, although often heavy traffic. It is possible the effects of horsepower may have differed if studied on high-speed rural highways, for example.

From 1985 to 2015, mean vehicle horsepower increased by 83% for cars, 168% for pickups, and 98% for SUVs. In contrast, from 1985 to 2014, the corporate average fuel economy increased by 32% (from 27.6 to 36.4 miles per gallon) for cars and 27% (from 20.7 to 26.3 miles per gallon) for light trucks in response to stricter federal fuel economy standards (National Highway Traffic Safety Administration, 2014). This suggests that automakers may have been putting more engineering expertise into using engine technology to increase power rather than achieving higher fuel economy. "It's the hour of power for Detroit's muscle cars," according to a recent newspaper story on modern performance cars (Phelan, 2015). The reporter noted the wide availability of high-performance vehicles at all price points, despite strict emissions limits, volatile gas prices, and concerns about climate change. In October 2015, Ford Motor Company announced the release of a limited number of special-edition Mustang GTs with 727 horsepower (Martinez, 2015). Given the demonstrated strong association between more powerful vehicles and higher speeds and collision rates, the ever-increasing trend in more power vehicles appears misguided.

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Table 1. Characteristics of roadways, observed passenger vehicle drivers, travel speeds, and vehicle power, overall and by observation site.

					Characteristics of drivers			Travel speeds			Vehicle power	
Roads	Vehicle counts	Speed limit (mph)	Number of lanes in each direction	Hourly traffic count per lane	Percent male	Percent age 29 and younger	Percent in lower education zip codes	Mean mph	Percent exceeding speed limit	Percent >10 mph over speed limit	Mean vehicle horse-power	Mean horse-power to 100-pound vehicle weight ratio
I-66 site 1	2,578	65	4	391	66.9	11.1	59.9	67.9	71.6	8.3	213.9	5.6
I-66 site 2	3,204	60	4	505	69.2	11.0	56.0	66.3	88.9	22.2	202.2	5.5
Prince Wm Pkwy site 1	2,475	55	2	424	66.7	13.4	82.0	61.2	89.9	20.3	210.5	5.5
Prince Wm Pkwy site 2	2,362	55	2	466	70.0	12.4	71.5	56.6	62.7	5.7	214.8	5.6
George Wash Pkwy	2,638	50	2	753	70.2	6.3	29.0	56.6	89.0	27.0	215.5	5.8
Fairfax Co Pkwy	3,876	50	2	711	66.8	7.6	37.6	55.2	84.6	16.3	207.1	5.6
US 50 site 1	2,607	45	2	503	63.2	9.6	45.4	44.8	47.8	3.0	196.4	5.5
US 50 site 2	3,132	45	2	579	63.6	10.3	43.1	43.7	37.3	2.0	193.8	5.5
Columbia Pike	1,234	40	2	306	59.3	9.0	64.7	43.3	76.3	7.4	191.2	5.4
Leesburg Pike	2,553	40	2	489	65.6	8.4	46.8	39.6	44.9	2.2	190.7	5.4
All sites	26,659	—	—	534	66.5	9.8	51.8	54.1	69.5	12.0	204.1	5.5

Table 2. Mean speeds, proportions of vehicles exceeding speed limit by any amount and by more than 10 mph, and mean horsepower per 100-pound vehicle weight by driver age, gender, and education status of zip code; speed limit; and vehicle type

	Number of observations	Mean speed (mph)	Percent exceeding speed limit	Percent exceeding speed limit by >10 mph	Mean horse-power per 100-pound vehicle weight
Driver age (years)					
29 and younger	2,625	55.7	73.2	15.3	5.5
30 and older	24,034	54.0	69.1	11.6	5.5
Driver gender					
Female	8,922	53.6	68.7	10.9	5.5
Male	17,737	54.4	69.9	12.5	5.5
Education status of driver zip code					
Lower education	13,808	55.1	70.7	11.7	5.5
Higher education	12,851	53.1	68.2	12.3	5.6
Speed limit					
40 and 45 mph	9,526	42.8	47.2	3.0	5.4
50 and 55 mph	11,351	57.1	82.2	17.5	5.6
60 and 65 mph	5,782	67.0	81.2	16.0	5.5
Vehicle type					
Cars	13,838	53.7	69.3	12.5	5.6
Non-sport cars	13,474	53.7	69.1	12.4	5.6
Sports car	364	56.0	76.6	17.0	7.7
Vans	2,366	52.5	65.8	7.4	5.1
Minivans	1,790	52.9	67.8	8.1	5.3
Cargo/large passenger vans	576	51.5	59.7	5.2	4.6
Pickups and SUVs	10,455	55.1	70.6	12.4	5.5
Pickups	2,764	56.3	70.0	11.7	5.3
SUVs	7,691	54.6	70.8	12.6	5.5

Table 3. Results of log-linear regression model of effects of vehicle power and other predictors on mean vehicle speed.

Parameter	Estimate	Percent change in mean speeds	Standard error	t value	Pr > |t|
Intercept	3.7631	—	0.0078	484.3	<0.0001
Male vs. female	0.0015	0.15	0.0014	1.01	0.311
Driver age 29 and younger vs. age 30 and older	0.0187	1.88	0.0023	8.13	<0.0001
Lower vs. higher education status of driver zip code	-0.0094	-0.93	0.0070	-1.33	0.1827
Speed limit 50 and 55 mph vs. 40 and 45 mph	0.3189	37.56	0.0080	39.73	<0.0001
Speed limit 60 and 65 mph vs. 40 and 45 mph	0.4663	59.41	0.0098	47.45	<0.0001
Pickups and SUVs vs. cars	-0.0007	-0.07	0.0014	-0.48	0.6314
Minivans and larger vans vs. cars	-0.0106	-1.06	0.0025	-4.28	<0.0001
Vehicles per hour per lane (per 100 vehicles)	-0.0124	-1.24	0.0007	-19.03	<0.0001
Horsepower per 100-pound vehicle weight	0.0080	—	0.0012	6.5	<0.0001
Interaction between horsepower per 100-pound vehicle weight and the following variables:					
Driver zip code lower vs. higher education status	0.0027	—	0.0012	2.14	0.0327
Speed limit 50 and 55 mph vs. 40 and 45 mph	-0.0030	—	0.0014	-2.13	0.0335
Speed limit 60 and 65 mph vs. 40 and 45 mph	-0.0038	—	0.0018	-2.15	0.0316

Table 4. Results of logistic regression model of effects of vehicle power and other predictors on likelihood that a vehicle was exceeding speed limit by any amount.

Parameter	Estimate	Percent change in odds	Percent change in likelihood	Standard error	p-value
Intercept	-0.8695	—	—	0.1126	<0.0001
Male vs. female	-0.0181	-1.79	-0.57	0.0303	0.5509
Driver age 29 and younger vs. age 30 and older	0.1949	21.52	5.79	0.05	<0.0001
Lower vs. higher education status of driver zip code	0.0591	6.09	1.86	0.0297	0.0467
Speed limit 50 and 55 mph vs. 40 and 45 mph	1.5724	381.82	71.83	0.0359	<0.0001
Speed limit 60 and 65 mph vs. 40 and 45 mph	1.5859	388.37	72.26	0.04	<0.0001
Pickups and SUVs vs. cars	-0.0511	-4.98	-1.58	0.0307	0.0965
Minivans and larger vans vs. cars	-0.0834	-8.00	-2.60	0.0514	0.1044
Vehicles per hour per lane (per 100 vehicles)	0.0536	5.51	1.62	0.0144	0.0002
Horsepower per 100-pound vehicle weight	0.089	9.31	2.67	0.0138	<0.0001

Table 5. Results of logistic regression model of effects of vehicle power and other predictors on likelihood that a vehicle was exceeding speed limit by more than 10 mph.

Parameter	Estimate	Percent change in odds	Percent change in likelihood	Standard error	p-value
Intercept	-4.9731	—	—	0.1814	<0.0001
Male vs. female	0.1046	11.03	9.71	0.0423	0.0134
Driver age 29 and younger vs. age 30 and older	0.3672	44.37	37.30	0.061	<0.0001
Lower vs. higher education status of driver zip code	-0.4885	-38.65	-35.58	0.1925	0.0111
Speed limit 50 and 55 mph vs. 40 and 45 mph	1.6481	419.71	361.01	0.0691	<0.0001
Speed limit 60 and 65 mph vs. 40 and 45 mph	1.8775	553.71	459.69	0.0704	<0.0001
Pickups and SUVs vs. cars	-0.0354	-3.48	-3.06	0.0411	0.3887
Minivans and larger vans vs. cars	-0.4322	-35.09	-32.12	0.0854	<0.0001
Vehicles per hour per lane (per 100 vehicles)	0.2013	22.30	19.12	0.0183	<0.0001
Horsepower per 100-pound vehicle weight	0.08	—	—	0.0238	0.0008
Interaction between horsepower per 100-pound vehicle weight and driver zip code lower vs. higher education status	0.0887	—	—	0.0331	0.0074

Table 6. Summary of modeling results of the effect of vehicle power on mean speeds on the likelihood that a vehicle was exceeding speed limit by any amount and by more than 10 mph.

Parameter	Mean speed		Exceeding speed limit by any amount			Exceeding speed limit by 10 mph		
	Estimate	Percent change	Estimate	Percent change in odds	Percent change in likelihood	Estimate	Percent change in odds	Percent change in likelihood
Effect of increase of 1 horsepower per 100-pound vehicle weight								
Overall effect	0.0073	0.73	0.089	9.3	2.67	0.1259	13.4	11.6
Effect on roads with 40 or 45 mph speed limit	0.0094	0.95						
Effect on roads with 50 or 55 mph speed limit roads	0.0064	0.64						
Effect on roads with 60 or 65 mph speed limit roads	0.0056	0.56						
Effect of increase of 3 horsepower per 100-pound vehicle weight*								
Overall effect	0.0073	2.21	0.089	30.6	7.7	0.1259	45.9	38.3
Effect on roads with 40 or 45 mph speed limit roads	0.0094	2.86						
Effect on roads with 50 or 55 mph speed limit roads	0.0064	1.93						
Effect on roads with 60 or 65 mph speed limit roads	0.0056	1.70						

*3 horsepower per 100-pound vehicle weight represents the difference between the 10th and 90th percentile horsepower per 100-pound vehicle weight in the study sample.

Table 7
Estimated percentage increases in mean speed and the likelihood that a vehicle exceeds the speed limit by any amount and by more than 10 mph for three vehicle models with varying amounts of vehicle power relative to a baseline vehicle with 3.3 horsepower per 100-pound vehicle weight

Horsepower per 100-pound vehicle weight	Exemplar model	Percent increase in mean speed relative to vehicle with 3.3 horsepower per 100-pound vehicle weight	Percent increase in likelihood that vehicle exceeds speed limit by any amount relative to vehicle with 3.3 horsepower per 100-pound vehicle weight	Percent increase in likelihood that vehicle exceeds speed limit by more than 10 mph vehicle with 3.3 horsepower per 100-pound vehicle weight
5.7	2015 Accord 4-cylinder engine	1.7	6.1	29.1
7.8	2015 Accord 6-cylinder engine	3.3	11.2	61.3
15.9	Dodge Challenger SRT Hellcat	9.6	25.9	233.1

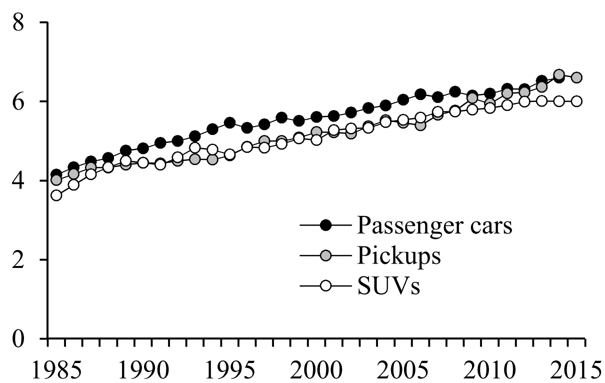

Fig. 1: Trends in mean power (horsepower per 100 pounds vehicle weight) for cars, pickups, and SUVs, 1985-2015 models.