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Relationship of Vehicle Weight to Fatality and Injury Risk

in Model Year 1985-93 Passenger Cars and Light Trucks

RELATIONSHIP OF VEHICLE WEIGHT TO FATALITY AND INJURY RISK IN MODEL YEAR 1985-93 PASSENGER CARS AND LIGHT TRUCKS

Large vehicles have historically been more stable and provided more protection for their own occupants than small ones, but they presented a greater hazard to other road users. Between 1985 and 1993, the population of light trucks - pickups, sport utility vehicles (SUV) and vans - increased by 50 percent in the United States. Since the major downsizing of passenger cars during 1975-82, light trucks have had a substantial and growing weight advantage over cars. By 1992, the number of fatalities in collisions between cars and light trucks exceeded the number in car-to-car collisions. In car-light truck collisions, 80 percent of the fatalities are occupants of the cars. That raises the question whether the growth in the number and weight of light trucks is having an adverse impact on the safety of passenger car occupants and other road users, possibly exceeding any safety benefits of the vehicle-weight increases for the occupants of the trucks.

During 1995, the National Highway Traffic Safety Administration (NHTSA) analyzed the historical relationship between vehicle mass and the risk of fatalities, serious or moderate injuries, and less-serious injuries. In view of the complexity and the high public interest in the issue, drafts of these studies were peer-reviewed by a panel of experts under the auspices of the Transportation Research Board of the National Academy of Sciences. In January 1997, the studies were revised in response to the panel's recommendations. The analyses assume that past relationships between weight and other size parameters, such as track width, wheelbase, center-of-gravity height, and structural strength would be maintained. They do not include the effects of potential future improvements in safety technology. Given those assumptions, what would be the effect of reducing or increasing the average weight of passenger cars - or of light trucks - by 100 pounds? Weight-safety relationships were analyzed for passenger cars and light trucks in each of the important crash modes. After a general overview of those relationships, the individual analyses are reviewed and discussed.

Effect of a 100-pound weight reduction for passenger cars

NHTSA estimates that a 100-pound reduction in the average weight of passenger cars, with accompanying reductions (based on historical patterns) in other size parameters such as track width, and in the absence of any compensatory improvements in safety technology, would have a significant adverse impact on safety:

- Fatalities would increase by an estimated 302, which would be 1.1 percent over the current level.
- Serious or moderate injuries (AIS 2-6) in nonrollover crashes would increase by 1,823, which would be 1.6 percent over the current level.
- Police-reported 'A' or 'K' injuries, which are usually less serious than AIS 2-6 injuries, would increase by 8,804 in nonrollover crashes, which would be 3.2 percent over the current level.

The estimate of the fatality increase includes the effect of car-weight reductions on all the people in crashes that involved at least one passenger car: not only the car occupants, but also the occupants of other vehicles, such as light trucks or motorcycles, involved in the crash, plus any pedestrians or bicyclists. In other words, they are the net effects on society, when car weight changes, and all other vehicles stay the same. The nonfatal-injury analyses include the effects on the occupants of any car or light truck involved in the crash (but not pedestrians, etc.).

Fatalities and injuries would increase in almost every crash mode. The largest absolute increase in fatalities would occur in collisions between cars and light trucks: a reduction in car weight would widen the disparity in the mass and strength of light trucks and cars. Rollover fatalities would experience the largest percentage increase: smaller cars are less stable and more prone to roll over. Fatalities and injuries would increase in collisions with fixed objects and other vehicles, since smaller cars are less crashworthy. These losses would only be slightly offset by a reduction of fatalities in pedestrian crashes.

The estimates indicate what might happen to fatalities and injuries if **historical** relationships are maintained between weight and other size parameters, such as track width, wheelbase, center-of-gravity height, and structural strength. The trends shown here are not necessarily what would happen if a specific vehicle were reduced only in weight but "everything else stayed the same" or if there were radical changes in the materials or design of vehicles. Specifically, the effect of weight reductions on fatalities in rollovers might be smaller if weight could be reduced without changing track width. Also, these trends could be offset by future improvements in safety equipment or design.

NHTSA has previously analyzed the weight-safety relationship in passenger cars, most recently in 1989-91. At that time the agency studied the effect of the major downsizing of passenger cars between 1975 and 1985: while new cars in the United States became twice as fuel-efficient, their average curb weight dropped by nearly 1000 pounds (from 3700 to 2700 pounds). Wheelbase decreased, on the average, by 10 inches and track width by 2 to 3 inches. NHTSA concluded that downsizing resulted in increases of nearly 2,000 fatalities and 20,000 serious or moderate injuries per year (i.e., about 200 fatalities and 2,000 serious or moderate injuries per 100 pounds). Those analyses, however, were incomplete. Weight-safety relationships were not estimated in collisions between cars and light trucks, pedestrians, bicyclists or motorcyclists. Collisions of cars with big trucks were only studied at the nonfatal injury level. The current analyses address all major crash modes. They are based on the crash experience of model year 1985-93 passenger cars during calendar years 1989-93, in order to take into account the effects of changes in the traffic environment since the mid-1980's:

- Increased use of safety belts has reduced risk in all types of crashes, especially in rollovers.
- Cars are sharing the roads with larger numbers of light trucks.
- Most of the large, heavy pre-1977 cars are gone.
- The proportions of older and female drivers have increased, while the proportion of young drivers has receded. That has reduced the frequency of rollovers relative to other crashes, such as intersection collisions.

- Older drivers have always favored larger cars, on the average, but that preference has become much stronger during the past ten years.

Effect of a 100-pound weight reduction for light trucks

The analyses completed in January 1997 permit NHTSA to estimate the safety effects of a 100-pound reduction in the average weight of light trucks (pickup trucks, SUVs and vans), with accompanying reductions in other size parameters. It appears that weight reductions would have fairly small net effects on safety, and they might actually reduce the total number of fatalities and serious or moderate injuries, when all road users are taken into account:

- Fatalities would be **reduced** by an estimated 40, which would be 0.3 percent below the current level. This reduction, however, is not statistically significant.

- Serious or moderate injuries (AIS 2-6) in nonrollover crashes would be **reduced** by 601, which would be 1.3 percent below the current level.

- Less-serious injuries (police-reported 'A' or 'K') in nonrollover crashes would increase by 1,794, which would be 1.5 percent over the current level.

These estimates include all occupant fatalities and injuries in crashes that involved at least one light truck: the truck occupants, plus the occupants of other light vehicles involved in the crash. Pedestrians and bicyclists are included in the analysis of fatal crashes, but not in the injury analyses. The estimates measure the net effects on society, when light trucks get smaller, but other vehicles stay the same size.

When trucks are reduced in weight and size, they become less crashworthy for their own occupants, but they become less capable of damaging other vehicles. In almost every crash mode, fatalities and injuries increased for the occupants of the light trucks, but those losses could be more than offset (except at the less-serious injury level) by benefits for smaller road-users: occupants of passenger cars, pedestrians, bicyclists and motorcyclists. As in the analysis for cars, it is assumed that historical relationships are maintained between weight and other size parameters. Interestingly, the correlation between mass and parameters that influence rollover stability has historically been much weaker for trucks than cars. As a result, weight reductions are expected to have little or no effect on fatalities in rollover crashes.

Effect of a 100-pound weight increase

The estimated effect of a 100 pound weight increase in cars or light trucks would be the opposite of a 100 pound reduction.

Conclusion: vehicle weight and safety

The results have a clear pattern: reducing a vehicle's weight increases net risk in collisions with substantially larger and stronger entities, **reduces** net risk in collisions with much smaller and more vulnerable entities, and has little effect on net fatalities in collisions with vehicles of about the same size (although nonfatal injuries increase). The only entities smaller than passenger cars are pedestrians, bicyclists and motorcyclists. Therefore, when car weight is reduced, the modest benefit for pedestrians is far outweighed by the increase in most other types of crashes. Light trucks, on the average, weigh 900 pounds more than passenger cars, and they are only exceeded in size and strength by big trucks and fixed objects. Continued growth in the number and weight of light trucks, unless offset by safety improvements, is likely to increase the hazard in collisions between the trucks and smaller road users. A reduction in truck weights is likely to generate significant benefits for pedestrians and car occupants that might exceed the added risk for the occupants of the trucks.

Other studies on vehicle size and safety

The Department of Transportation is not alone in being concerned over the size and weight of vehicles and the resultant effect on safety. During the past 18 years, numerous public and private groups have studied the relationship of passenger car size to safety. The Office of Technology Assessment of the United States Congress, the National Safety Council, the Brookings Institution, the Insurance Institute for Highway Safety, the General Motors Research Laboratories and the National Academy of Sciences all agreed that reductions in the size and weight of passenger cars pose a safety threat.

These studies did not analyze weight-safety relationships for light trucks. The report by the National Academy of Sciences expressed concern about the growing numbers of light trucks, noting that collisions between light trucks and cars are often very damaging to the cars.

Effects of regulations and improved traffic safety

Occupants of vehicles of all sizes benefit from continuing improvements in vehicle and road safety design, increased belt use, reduced alcohol involvement, state and local safety programs and other factors. Demographic and societal trends, such as a reduction in the young-driver population, a more urban population, and rising interest in health and safety are also curtailing fatality rates. The long-term reduction in overall fatality risk has far overshadowed the adverse effect of car downsizing. Similarly, the adverse effect of future reductions in car weight could be offset by new safety technology.

One of the principal improvements has been the increase in the use of safety belts and child safety seats. NHTSA estimates that if **all** passenger vehicle occupants used these devices, 10,035 of the fatalities that occurred in 1995 could have been saved [*Traffic Safety Facts 1995 - Occupant Protection*]. An excellent way to combat the safety problem of smaller cars is to increase belt use.

SUMMARIES OF THE ANALYSES

The counts of fatalities in 1993 in each of the important types of crashes involving passenger cars and/or light trucks (pickups, SUVs and vans), according to the Fatal Accident Reporting System (FARS - a census of fatal crashes), were as follows:

	Fatalities in 1993	
	Cars	Light Trucks
Principal rollovers (not resulting from a collision)	1,754	1,860
Collisions with objects (e.g., impacts with trees)	7,456	3,263
Collisions with pedestrians, bicycles, motorcycles	4,206	2,217
Collisions with trucks over 10,000 pounds (Gross Weight)	2,648	1,111
Collisions between passenger cars	5,025	
Collisions between light trucks		1,110
Collisions between passenger cars and light trucks	5,751	

These counts include all fatalities in the crash: occupants of any vehicles involved in the crash, plus pedestrians and bicyclists. The goal of the analyses is to estimate relationships between curb weight and fatality or injury risk for recent cars and light trucks. "Fatality or injury risk" includes all casualties in the crash: the objective is to find the net effect on society when vehicle weight is changed. "Recent" cars and trucks are usually model years 1985-93, and the analyses are based on their crash experience during 1989-93. (But the analyses of serious or moderate injuries are based on a smaller data file, and they were extended to vehicles of all ages in 1981-93 crashes, in order to assure an adequate sample size.)

Separate analyses are performed for each of the major crash types, since the weight-safety effect can vary considerably among crash modes. Each analysis estimates the percentage change in fatalities [or injuries] if all passenger cars [or light trucks] were to be reduced in weight by 100 pounds, but everything else on the road stays the same. It is assumed that the 100-pound weight reduction would be accompanied by corresponding reductions in other size parameters, such as track width or structural strength, based on historical correlations among those parameters. The analyses of collisions between passenger cars and light trucks are performed twice: once, to find the effect of a 100-pound reduction in the cars, while the light trucks are unchanged; and once, to estimate what happens if the trucks are reduced by 100 pounds, but the cars stay the same.

The analyses of fatalities are based on death rates per million vehicle years. They estimate the net effect of vehicle weight on crash proneness (crash risk per unit of exposure) and crashworthiness (fatality risk, given a crash). The analyses of injuries, on the other hand, are based on injuries per 100 crash-involved drivers: they only estimate the effect of weight on crashworthiness. Such analyses would not estimate meaningful weight-safety relationships in rollover crashes (where the primary effect of vehicle weight is on crash proneness, not crashworthiness) or pedestrian crashes (where the pedestrians, not the drivers, are injured), and they are omitted for that reason.

Effect on fatalities

The analyses are based on crash data from the 1989-93 FARS and vehicle registration data from R.L. Polk's *National Vehicle Population Profiles* for 1989-93. Fatality rates per million exposure years (which include fatalities to occupants of all vehicles in the crash, plus any pedestrians) are computed by make, model and model year, based on the crash experience of model year 1985-93 vehicles in the United States. Regression analyses calibrate the relationship between curb weight and the fatality rate, adjusting for the effects of driver age and sex, vehicle age, State, urban-rural, daytime-nighttime and other confounding factors. Information about the age of the "average" driver in each make-model, and many of the other control variables, is derived from 11 State accident files for 1989-93, based on crash involvements in which vehicles were standing still (waiting for traffic to clear or a green light) and got hit by somebody else. The regression analyses estimate the percentage increase or decrease in fatalities (including occupants of other vehicles and pedestrians) per 100 pound weight reduction in cars or in light trucks. The percentage changes are applied to the 1993 "baseline" fatality counts, as shown above, to estimate the absolute effects.

If all **passenger cars** on the road were reduced in weight by 100 pounds, while light trucks and other vehicles remained unchanged, the following impacts on fatalities are estimated:

PASSENGER CARS: EFFECT OF 100 POUND WEIGHT REDUCTION ON FATALITIES
(light truck weights unchanged)

Crash Type	Fatalities in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Fatality Change
Principal rollover	1754	+ 4.58%	+ 80
Hit object	7456	+ 1.12%	+ 84
Hit ped/bike/motorcycle	4206	- .46%	- 19
Hit big truck	2648	+ 1.40%	+ 37
Hit another car	5025	- .62% (nonsignificant)	- 31
Hit light truck	5751	+ 2.63%	+ 151
OVERALL	26840	**+ 1.13%**	**+ 302**
±2-sigma confidence bounds			**+214 to +390**
±3-sigma confidence bounds			**+170 to +434**

Additional downsizing of passenger cars would significantly increase fatalities in rollovers, collisions with objects, big trucks, and above all, light trucks. The harm would be only slightly offset by a modest benefit for pedestrians, bicyclists and motorcyclists. There would be little net effect on fatalities in car-to-car collisions, if both cars in the collision were downsized. The largest relative increase, 4.58 percent, would be in principal rollovers, given the historical tendency that less mass means narrower, shorter, less stable cars. But the greatest absolute increase, 151 fatalities, would be in collisions between cars and light trucks, which were a much bigger safety problem in "baseline" 1993 (5,751 fatalities) than principal rollovers (1,754 fatalities). In car-light truck collisions, 80 percent of the fatalities are occupants of the cars, because the light trucks already outweigh the cars by 900 pounds, on the average. If cars were further reduced in mass, the additional risk to the car occupants far exceed the small benefit that reduction would have for the occupants of the light trucks.

Overall, a 100-pound reduction in the average weight of passenger cars is estimated to result in 302 additional fatalities, which would be a 1.13 percent increase over the baseline. This overall increase is statistically significant. Its 2-sigma confidence bounds range from 214 to 390. Two-sigma confidence bounds have been considered wide enough to include the likely range of error in past NHTSA evaluations. Given this evaluation's complex analysis approach, it might be appropriate to consider wider, 3-sigma confidence bounds. They range from 170 to 434. Either set of confidence bounds supports a conclusion that car weight reductions, given historical patterns of car design, would be associated with increases in fatalities. This estimate is higher than NHTSA's 1991 study (approximately 200 lives per 100 pounds), only because the earlier study did not address collisions of cars with light trucks, big trucks and pedestrians.

Some people believe that small cars attract aggressive drivers because they are more sporty and powerful than large cars. They might argue that, to a greater or lesser extent, it's not the cars, but rather their drivers that are responsible for the higher fatality rates of small cars in the preceding analyses. This belief may have been valid at one time, but today, the typical small car is no longer a sports car. The make-models currently associated with high performance, high horsepower, or aggressive driving are generally not small, but are of average or even slightly heavier-than-average weight. As a result, the high-performance make-models, if anything, biased the preceding analyses in favor of smaller cars. In a sensitivity test, the analyses of this report were re-run without those sporty and high-performance make-models. The correlation between passenger car weight and fatality risk did not diminish. In fact, it became slightly stronger. The predicted effect of a 100-pound weight reduction escalated from an increase of 302 fatalities in the baseline analysis to an increase of 370 fatalities on the sensitivity test.

Between 1985 and 1993, the average weight of a new light truck increased by 340 pounds. If this trend were to be reversed, and all **light trucks** on the road were reduced in weight by 100 pounds, while passenger cars and other vehicles remained unchanged, the following impacts on fatalities are estimated:

LIGHT TRUCKS: EFFECT OF 100 POUND WEIGHT REDUCTION ON FATALITIES
(passenger car weights unchanged)

Crash Type	Fatalities in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Fatality Change
Principal rollover	1860	+ .81% (nonsignificant)	+ 15
Hit object	3263	+ 1.44%	+ 47
Hit ped/bike/motorcycle	2217	- 2.03%	- 45
Hit big truck	1111	+ 2.63%	+ 29
Hit passenger car	5751	- 1.39%	- 80
Hit another light truck	1110	- .54% (nonsignificant)	- 6
OVERALL	15312	**- .26%**	**- 40**
±2-sigma confidence bounds			**-100 to +20**
±3-sigma confidence bounds			**-130 to +50**

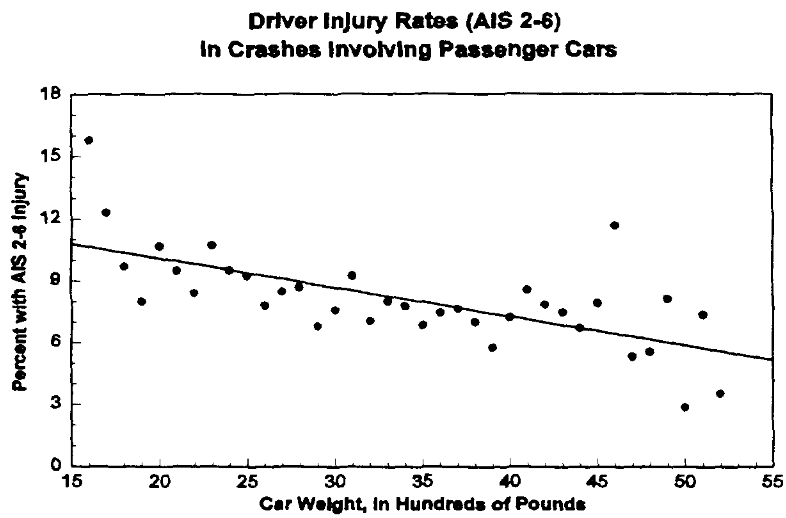
Reducing the mass of light trucks would significantly increase the fatality risk of their occupants in collisions with objects and big trucks. But downsizing of light trucks would significantly reduce risk to pedestrians, motorcyclists and, above all, passenger car occupants. There would be little effect on rollovers because, historically, there has been little correlation between the mass of light trucks and their rollover stability (width relative to center-of-gravity height). There would also be little change in collisions between two light trucks, if both trucks are reduced in mass.

Even though the effect of mass reductions is statistically significant in four of the six types of crashes, the net effect for all types of crashes combined is small, because some of the individual effects are positive and others are negative. The benefits of truck downsizing for pedestrians and car occupants could more than offset the fatality increase for light truck occupants. It is estimated that a 100-pound reduction could result in a modest net savings of 40 lives, (0.26 percent of baseline fatalities). However, this estimate is not statistically significant: the 2-sigma confidence bounds range from a savings of 100 to an increase of 20 fatalities; the 3-sigma bounds range from a savings of 130 to an increase of 50 fatalities. It is concluded that a reduction in the weight of light trucks would have a negligible overall effect, but if there is an effect, it is most likely a modest **reduction** of fatalities.

Effect on serious or moderate (AIS 2-6) injuries

The association between vehicle curb weight and a driver's risk of serious or moderate injury in light vehicle towaway crashes was used to estimate the effect of changes in vehicle weight on annual occupant (driver and passenger) serious or moderate injuries. This analysis is based on data collected in the 1981-1993 National Accident Sampling System (NASS). Serious or moderate injuries included those of levels 2 to 6 on the Abbreviated Injury Scale [as well as all fatalities, regardless of their AIS level].

Passenger car crashes -- The NASS data used here include 71,799 investigated cases of drivers that fit one of the following two criteria: each was driving either a passenger car towed from any type of crash (except a principal rollover) or a light truck (that is, a pickup truck, passenger van, or utility vehicle) that was towed after involvement with a passenger car. The drivers of light trucks that hit cars are included because the goal is to measure the net impact on all road users of a weight reduction in the passenger cars. The injury rates for these drivers were summarized as a function of the weight of the passenger car, in 100-pound ranges:



The line fit through the 37 data points based on at least 100 investigated cases has an R-squared of 0.44 and the equation:

Serious/Moderate Injury Rate = 12.90165 - 0.0014074 * car weight

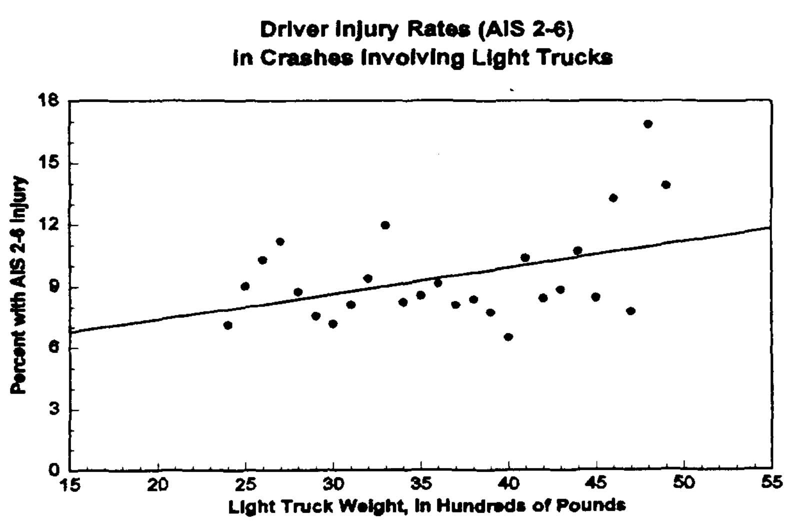
The model suggests that the injury rate increases by 1.6 percent (from 8.679 to 8.820) when car weight drops from 3000 pounds (the current average weight of cars on NASS) to 2900 pounds.

NASS data, when weighted by sampling rates, can be used to estimate the total number of crashes or injuries in the United States. There were an estimated 112,430 serious or moderate injuries in crashes of this type in the United States in 1993. Thus, the model suggests that there would have been an increase of 1,823 serious or moderate injuries among occupants of light vehicles towed from a crash in 1993 if every passenger car had been one hundred pounds lighter and if there were no changes in the weights of light trucks. This overall increase is statistically significant. Its 2-sigma confidence bounds range from 1,152 to 2,462. This estimate includes **all** towaway crash modes (except principal rollovers and nonmotorist-injury crashes) and it includes the effects of passenger car weight reductions on injuries to both passenger car occupants and occupants of light trucks involved in crashes with passenger cars. Separate analyses were also performed on four individual crash modes.

PASSENGER CARS: EFFECT OF 100 POUND WEIGHT REDUCTION ON AIS 2-6 INJURIES
(light truck weights unchanged)

Crash Type	AIS 2-6 Injuries in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Injury Change
Hit object	63,215	+ 1.7%	
Hit big truck	1,338	nonsignificant	
Hit another car	26,521	+ 2.0%	
Hit light truck	21,356	+ .9%	
All nonrollover crashes	112,430	**+ 1.6%**	**+ 1,823**
±2-sigma confidence bounds			**+1,152 to +2,462**

Light truck crashes -- The NASS data used here include 19,329 investigated cases of drivers that fit one of the following two criteria: each was driving either a light truck towed from any type of crash (except a principal rollover) or a passenger car that was towed after involvement with a light truck. The injury rates for these drivers were summarized as a function of the light truck weight, in 100-pound ranges:



The line fit through the 26 data points based on at least 100 investigated cases has an R-squared of 0.17 and the equation:

$$\text{Serious/Moderate Injury Rate} = 4.87235 + 0.0012601 * \text{truck weight}$$

The injury rate **decreases** by 1.3 percent (from 9.409 to 9.283) when light truck weight drops from 3600 pounds (current average weight of light trucks on NASS) to 3500 pounds.

There were an estimated 44,892 serious or moderate injuries in crashes of this type in 1993. Thus, the model suggests that there would have been 601 fewer serious or moderate injuries among occupants of light vehicles towed from a crash in 1993 if every light truck had been one hundred pounds lighter and if there were no changes in the weights of passenger cars. This overall reduction is statistically significant. Its 2-sigma confidence bounds range from 49 to 1,160. This estimate includes the effects of light truck weight reductions on injuries to both occupants of light trucks and passenger car occupants involved in crashes with light trucks. Additional analyses were performed on the individual crash modes.

LIGHT TRUCKS: EFFECT OF 100 POUND WEIGHT REDUCTION ON AIS 2-6 INJURIES
(passenger car weights unchanged)

Crash Type	AIS 2-6 Injuries in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Injury Change
Hit object	20,259	+ 1.9%	
Hit big truck	1,002	nonsignificant	
Hit passenger car	21,356	- 2.6%	
Hit another light truck	2,275	nonsignificant	
All nonrollover crashes	44,892	**- 1.3%**	**- 601**
±2-sigma confidence bounds			**-1,160 to -49**

The results for collisions with objects suggest that vehicle weight has some protective effect, for both cars and light trucks. A recently completed NHTSA analysis suggests that at least part of the protective effect derives from the ability of heavier vehicles to damage or displace a significant proportion of "fixed" objects. The results for collisions with big trucks do not show a significant protective effect of light vehicle's weight for either cars or light trucks; this may reflect either the overwhelming weight of the heavy truck or the small number of investigated cases available for this analysis.

In car-to-car crashes, there is an estimated 2.0 percent increase in the injury rate for a drop of 100 pounds in each car. The lack of statistically-significant results for crashes involving two light trucks may mean either that light truck weight has no more than a small effect on safety in these crashes or that the small number of investigated cases of this type were inadequate for detecting the weight effect.

The results for crashes involving both a car and a light truck suggest that increasing the weight of the car or decreasing the weight of the light truck would decrease the overall injury rate in the crashes. Since the light truck tends to be the heavier vehicle in these collisions, the result is consistent with a recently completed NHTSA analysis of the weight difference in NASS car-to-car collisions. That analysis indicates that smaller differences between the two car weights are associated with lower injury risk for the crash as a whole.

In summary, these results suggest that the risk of serious or moderate injury (in the light-vehicle fleet as a whole) would increase if cars were lighter but would decrease if light trucks were lighter. In general, the findings on serious or moderate injuries are similar to the results for fatalities.

Effect on less-serious ('A' or 'K') injuries

The analyses are based on State accident data from Illinois (1990-92) and Florida (1991-93). Injury rates per 100 crash-involved drivers were analyzed for model year 1985-93 passenger cars and light trucks (pickups, SUVs and vans). Only drivers with injuries classified as "incapacitating" (level A) or fatal (level K) were counted as "injured." Although level A injuries are defined as "incapacitating," in actual practice they include many less-serious lesions. Level A does not correspond to any specific level on the Abbreviated Injury Scale (AIS), but it would appear that the majority of level A injuries are minor (AIS = 1).

The goal of the analyses was to estimate the effect on per-crash injury rates that would result if some or all of the passenger vehicles were reduced in weight by 100 pounds. Two scenarios were considered: (1) any passenger cars in the crash would be reduced by 100 pounds and all light trucks unchanged; or (2) any light trucks would be reduced by 100 pounds and passenger cars unchanged. For each of these two scenarios, the weight-safety effect was assessed in collisions with fixed objects, with heavy trucks, with passenger cars and with light trucks.

The analyses were performed by logistic regressions in which an observation corresponded to a crash-involved vehicle and a positive response was K or A injury to the driver. The analyses calibrated the injury rate by curb weight, adjusting for the effects of driver age and urban-rural. In the analyses of collisions with fixed objects and heavy trucks, where only one light vehicle was involved per crash, the model included that vehicle's weight as an independent variable. In the analyses of collisions between two light vehicles, the model included the weights of each vehicle, or the weight of one vehicle and the difference between the two weights, as independent variables. In the collisions between passenger cars and light trucks, the effect on injury risk was calibrated both for the car drivers and the light truck drivers.

The estimated effects of a 100-pound weight reduction are as follows:

PASSENGER CARS: EFFECT OF 100 POUND WEIGHT REDUCTION ON 'A' OR 'K' INJURIES
(light truck weights unchanged)

Crash Type	'A' or 'K' Injuries in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Injury Change
Hit object	68,703	+ 3.8%	+ 2,629
Hit big truck	14,009	+ 3.5%	+ 493
Hit another car	119,039	+ 3.1%	+ 3,673
Car-light truck collisions			
Car occupants	48,546	+ 4.8%	+ 2,332
Light truck occupants	25,642	- 1.3%	- 323
All nonrollover crashes	275,939	**+ 3.2%**	**+ 8,804**
±2-sigma confidence bounds			**+7,438 to +10,170**

LIGHT TRUCKS: EFFECT OF 100 POUND WEIGHT REDUCTION ON 'A' OR 'K' INJURIES
(passenger car weights unchanged)

Crash Type	'A' or 'K' Injuries in 1993 Crashes	Effect of 100 Pound Weight Reduction	Net Injury Change
Hit object	26,544	+ 1.6%	+ 414
Hit big truck	3,966	+ 3.6%	+ 144
Hit another light truck	12,550	+ 3.2%	+ 407
Car-light truck collisions			
Car occupants	48,546	- 1.4%	- 685
Light truck occupants	25,642	+ 5.9%	+ 1,515
All nonrollover crashes	117,248	**+ 1.5%**	**+ 1,795**
±2-sigma confidence bounds			**+1,131 to +2,459**

In all cases, weight reductions were associated with increased injury risk for the vehicle's own driver. The estimated percentage increase in the driver injury rates, in response to a 100-pound weight reduction, ranged from 1.6 percent for light trucks that hit fixed objects to 5.9 percent for light trucks that collide with passenger cars. In collisions between cars and light trucks, a weight reduction for one of the vehicles was associated with a small beneficial effect for the driver of the vehicle that was not reduced in weight.

To estimate the impact of weight reductions on the absolute number of occupant injuries, these estimated percentage changes were applied to baseline numbers of injuries derived from the NHTSA General Estimates System (GES), 1993. The baseline numbers include injured passengers as well as drivers; the estimated change in injury probability to the driver is attributed to all of the occupants of the passenger vehicle.

Reducing the passenger cars by 100 pounds, while leaving the light trucks unchanged, would cause an estimated 8,804 additional less-serious injuries per year. This overall increase is statistically significant. Its 2-sigma confidence bounds range from 7,438 to 10,170. Reducing the light trucks by 100 pounds, while leaving the passenger cars unchanged, would cause an estimated 1,794 additional injuries per year. This increase is also statistically significant. Its 2-sigma confidence bounds range from 1,131 to 2,459.

The results for less-serious injuries show a stronger weight-safety effect than the analyses of fatalities and serious injuries. Also, in the collisions between cars and light trucks, injury risk appears to be influenced much more by the weight of the driver's own vehicle than by the weight of the other vehicle. For less-serious injuries, unlike fatalities and serious or moderate injuries, a reduction in the weight of light trucks causes more harm to the truck occupants than benefit to car occupants. As a result, the net effect of a weight reduction for light trucks is an increase of less-serious injuries, although not nearly as large an increase as the one predicted for a weight reduction in passenger cars.

REFERENCES

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Effect on fatalities

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