On equal footing: Trends in ankle/foot injuries for men vs. women

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ABSTRACT

Objectives: The objective of the current study was to examine trends in ankle/foot (A/F) injuries during the period 2001–2014, in order to determine whether the incidence of these injuries has changed and whether a previously identified difference in risk by gender still existed. In addition, other driver and crash-related risk factors were examined separately for men and women.

Methods: Passenger vehicle drivers aged 16 + were identified from NASS-CDS; weighted data were analyzed for model years 2001–2014. Model years (MY) were grouped as 2001–2004 (older) vs. 2005–2014 (newer), and drivers in frontal crashes were included. Ankle injuries included fractures and dislocations to the malleolus and distal tibia/fibula. Foot injuries included fractures and dislocations of the talus, calcaneus, and tarsal/metatarsal bones. Logistic regression models were constructed to identify risk factors, including MY, age, belt use, toepan/instrument panel intrusion, and body mass index (BMI) separately for each gender using odds ratios.

Results: The incidence of A/F injuries declined significantly between older and newer MY, especially for women. Whereas before MY 2005, ankle and foot injury risk was significantly higher for women than men, risks for ankle injury are now virtually the same for both genders, and women are only 1.2 times more likely than men to sustain a foot injury in a frontal crash. From multivariable regression models, however, it is apparent that there are different risk factors for A/F injuries for men vs. women. Body weight was a significant factor for both groups, but for men it was a risk only for those extremely obese, whereas for women those who were categorized as overweight were also at increased risk. Age greater than 55 was also found to be a risk factor for foot injuries among women but not men. For men and women, toepan intrusion remained the most important factor for both foot and ankle injuries, with significantly higher odds ratios noted for men. Foot pedals were a more likely injury source for women, whereas the toepan was more likely for men. In addition, belt use was protective for ankle injuries in women but not men.

Conclusions: Significant declines in A/F injuries have been noted in recent years, especially for women, whose risks are now similar to those for men. However, significant risk factors remain for each gender, primarily related to body habitus (BMI) and toepan intrusion. Age was a risk factor for foot injuries among women, for whom the foot pedals were more likely to be an injury source. Toepan intrusion remains a major factor for both men and women, but, with the exception of 30 + cm of intrusion, odds ratios were primarily much higher for men in each category of intrusion.

Introduction

Lower extremity injuries are common in motor vehicle collisions, with ankle/foot injuries having the highest incidence (Ye, Funk, et al. 2015). These injuries are quite disabling and have become relatively more important because, with the advent of seat belts and airbags, occupants are now surviving serious, high-impact crashes but are left with life-altering lower limb injuries. As reported in Ye, Funk, et al. (2015), lower extremity injuries account for 45% of all Abbreviated Injury Scale (AIS) 2+ injuries among front seat occupants in frontal crashes.

Ankle/foot injuries occur primarily in frontal collisions and are sometimes, but not always, associated with intrusion of the toepan and/or instrument panel (Austin 2012). In a previous study, an association was found between driver gender and risk of ankle/foot injuries; further analyses, however, showed that, regardless of gender, shorter drivers had an increased risk (Dischinger et al. 1995). Other studies have also shown associations between ankle/foot injuries and gender (Austin 2012; Rudd 2009) as well as body mass index (BMI; Austin 2012; Chong et al. 2007). Injuries to articular surfaces, such as pilon fractures, are especially disabling and costly (Dischinger et al. 2005; Read et al. 2004).

Improvements in vehicle crashworthiness and restraint systems have led to reductions in intrusion to the toepan and instrument panel of the vehicle (Rudd 2009) and reduced axial loads to the foot, leg, and ankle in standardized crash tests. Despite these improvements, an analysis of NASS-CDS data for the period between 1994 and 2007 suggested that the prevalence of ankle and foot injuries had not decreased in newer model year vehicles and may have actually slightly increased (Rudd 2009).
In a more recent analysis of NASS data for model years 1998–2010, Ye, Funk, et al. (2015) noted declines in the incidence of whole-body AIS 2+ injuries for drivers in frontal crashes, but lower extremity injuries remained the most frequently injured body region. However, neither of these studies examined the incidence and risk factors for men and women separately. The goal of this study was to examine trends in ankle/foot injuries between 2001 and 2014 to determine whether the incidence of these injuries has declined, determine whether the previously identified gender difference in risk still exists, and identify specific risk factors that remain for both men and women.

Methods

Approach

Data were obtained from the NASS-CDS (NHTSA 2015). The crashes included in each survey year of the NASS-CDS file are selected by a multistage weighted probability sample of all police-reported tow-away collisions that take place in the United States during that particular year. The NASS-CDS data represent a sample of passenger cars, SUVs, vans, and light trucks and are weighted to determine national estimates of the type of crashes and injuries occurring in motor vehicle collisions on U.S. roadways. Approximately 5,000 motor vehicle crashes are sampled each survey year.

Drivers in frontal collisions were selected for analysis, given the high risk of ankle/foot injuries. Comparisons were made between 2 model year (MY) groups, vehicles manufactured between 2001 and 2004 vs. those produced between 2005 and 2014, based on evidence that safety assessments showed considerable improvements by 2005. Furthermore, as shown by Ye, Poplin, et al. (2015), based on Insurance Institute for Highway Safety crash tests, there have been significant decreases in vehicle foot well and toepan intrusion, foot accelerations, tibia axial forces, and tibia index with increasing model years. Steep declines were noticeable from 1995 through 2004, with steadier declines from 2005 to 2013 (Ye, Funk, et al. 2015). Because the risk of ankle and foot injuries shows different epidemiologic patterns for men and women (Austin 2012; Dischinger et al. 1995; Rudd 2009), analyses were separated by both gender and ankle or foot injury.

Data analyses

For the current study, NASS-CDS records were obtained for drivers aged 16 years or older who were operating passenger vehicles involved in frontal (principal direction of force of 11, 12, or 1 o’clock) or frontal shift crashes during vehicle MY 2001–2014. Frontal shift refers to frontal impact damage along with a “shifting” or movement of the end structure(s) of a vehicle (≥4 in./10 cm) as measured at the frame rails or longitudinal measures (NHTSA 2015). Statistical analyses were completed using weighted NASS-CDS data unless indicated otherwise. SAS 9.3 software was used to apply sampling stratification information and correctly compute standard errors. Foot injuries were defined as a fracture or dislocation of the talus, calcaneus, tarsal, or metatarsal bones. Ankle injuries included a fracture or dislocation to the malleolus or distal tibia or fibula bones. A P-value below .05 was considered statistically significant.

No differences were found for change in velocity or type of object/vehicle struck when comparing the 2 MY groups. There was a significant decline in pickup truck-related injuries in the newer MY group; though there was a higher risk of ankle/foot injury among drivers of pickup trucks, the numbers of cases were quite small (less than 70), so this difference was not given further consideration.

For each type of lower extremity injury (i.e., foot or ankle), the primary hypothesis involved a comparison of the incidence of injury occurring in MY 2001–2004 versus MY 2005–2014, because most vehicles had high safety ratings by 2005 (O’Neill 2005). Secondary hypotheses assessed whether gender differences existed for these injuries when comparing MY groups. For these hypotheses, the incidence of foot and ankle injuries was determined for each MY group, along with the odds ratio (OR) and corresponding 95% confidence interval (CI). These statistics were also computed separately for men and women. To account for the complex weighting design of the NASS-CDS data, comparisons of categorical variables were carried out using the Rao-Scott chi-square test.

Further analysis involved the application of separate weighted logistic regression models for men and women to examine potential crash and host related risk factors for foot and ankle injuries. Odds ratios and 95% CIs were computed for each independent variable. A final analysis compared the incidence of injury occurring during the 2 most recent model periods (i.e., MY 2005–2009 vs. MY 2010–2014) to ascertain more current trends among men and women drivers.

Crash characteristics that were analyzed in logistic regression models included seat belt use (yes/no), airbag deployment (yes/no), change in velocity, toepan and instrument panel intrusion (yes/no), and centimeters of intrusion (relative to 2 cm or less). Airbag deployment and change in velocity were highly correlated with level of intrusion, so the former 2 variables were excluded from the models (Tables A1 and A2, see online supplement). In addition, intrusion level data were more complete, because change in velocity was unavailable for 37% of cases. Intrusion levels in the NASS-CDS data set are categorized as ≤2 cm, 3–7 cm, 8–14 cm, 15–29 cm, 30–45 cm, 46–60 cm, 61+ cm, and catastrophic. Due to the relatively small number of vehicles with a high magnitude of intrusion, the last 4 categories were combined as “30+ cm.”

Host-related factors included driver age (55+ vs. <55), gender, and body mass index (BMI; relative to normal weight). The age cutoff was based on guidelines from the American College of Surgeons, indicating that age 55 should be considered as “elderly,” given the need for triage to a trauma center and the higher risk of mortality (Jacobs et al. 2003). This cutoff, based on research conducted 2 decades ago, is commonly used in trauma research (Finelli et al. 1989). The definition of BMI was obtained from the Centers for Disease Control (2015): <18.5 (underweight); 18.5–24.9 (normal); 25.0–29.9 (overweight); 30.0 or higher (obese). The last category was further subdivided as 30.0–39.9 (obese) and 40.0 or higher (extremely obese).

Additional tables were constructed to analyze the most likely sources located in the vehicle that can be attributed to each foot and ankle bone injury using unweighted NASS-CDS data. Occupant injuries were each identified by their AIS score and interior injury sources (i.e., contact points) were tallied separately for bones in the right and left feet. Contact points for foot and
ankle were compared between men and women and categorized as the floor (including the toepan, console-mounted transmission lever, and console) and foot controls (including the accelerator, brake, and parking brake). All comparisons of unweighted data were made using Pearson’s chi-square statistic.

**Results**

A total of 19,174 unweighted cases representing 7,560,854 weighted cases were analyzed. The unweighted data included 10,268 men (53.6%) and 8,906 women (46.4%; Table A3, see online supplement). There were 488 foot injuries and 386 ankle injuries sustained among the 19,174 drivers, with 1.8% of drivers incurring more than one foot or ankle injury.

Weighted analyses of NASS-CDS data indicated that the incidence of foot and ankle injuries declined significantly between MY 2001–2004 and MY 2005–2014 (Table 1). For foot injuries, odds ratios indicated a 76% reduction in incidence (2.03 vs. 0.49%, OR = 0.36, 95% CI, [0.22–0.52]). As found for foot injuries, women experienced a slightly larger (33%) reduction (0.52 vs. 0.39%, OR = 0.34, 95% CI, [0.22–0.52]).

**Table 1.** Incidence of injuries in weighted NASS data. Passenger vehicle drivers in frontal crashes, MY 2005–2014 relative to 2001–2004.

| Parameter       | 2001–2004 (%) | 2005–2014 (%) | P     | OR   | 95% CI for OR |
|-----------------|---------------|---------------|-------|------|---------------|
| Foot injuries   |               |               |       |      |               |
| All             | 2.03          | 0.49          | <.01  | 0.24 | 0.10–0.59     |
| Females         | 3.44          | 0.59          | <.01  | 0.17 | 0.06–0.50     |
| Males           | 0.68          | 0.39          | <.01  | 0.58 | 0.29–1.16     |
| Ankle injuries  |               |               |       |      |               |
| All             | 0.83          | 0.28          | <.01  | 0.34 | 0.22–0.52     |
| Females         | 1.25          | 0.35          | <.01  | 0.28 | 0.10–0.74     |
| Males           | 0.43          | 0.23          | <.01  | 0.51 | 0.15–1.69     |

Significant risk factors for ankle injuries occurring among female drivers were older MY, intrusion, and BMI of 30 or higher (Table 3). Belt use was a protective factor for women. Model year of the vehicle did not matter for men because risk factors again included intrusion (8 or more cm) and BMI of 40 or higher. However, a low BMI (<18.5, underweight) was protective for ankle injury.

The finding of BMI as an important risk factor may be related to weight rather than height. Male to female height was generally the same for both foot injury (69 to 65 in.) vs. no foot injury (69 to 64 in.) and ankle injury (70 to 66 in.) vs. no ankle injury (69 to 64 in.). However, the male to female weight ratio decreased from 214 to 194 lb. for foot injury to 190 to 152 lb. for no foot injury and from 246 to 210 lb. for ankle injury to 190 to 153 lb. for those without.

Having found a reduction in foot and ankle injuries during the most recent 10-year period, relative to MY 2001–2004, further analyses compared MY 2005–2009 with MY 2010–2014 vehicles. As displayed in Table 4 there were still further reductions in foot and ankle injury occurrence in MY 2010–2014 vehicles, though each reduction was small and none were statistically significant. For foot injuries, odds ratios indicated a 22% reduction in incidence (0.52 vs. 0.39%, OR = 0.78, 95% CI, [0.36–1.61]). Women experienced a slightly larger (33%) reduction in recent MY vehicles and men experienced a 12% reduction in MY 2005–2009 vehicles compared to MY 2010–2014 vehicles.

**Table 2.** Weighted NASS analysis of drivers in frontal crashes. Outcome = Incidence of foot injury.

| Parameter       | 2005–2014 (%) | 2005–2014 (%) | P     | OR   | 95% CI for OR |
|-----------------|---------------|---------------|-------|------|---------------|
| Females         |               |               |       |      |               |
| MY 2005–2014    | .01           | .01           | <.01  | .11  | 0.05–27.00    |
| Age 55+         | .01           | .01           | <.01  | .63  | 1.75–23.15    |
| Belted          | .53           | .74           | <.01  | .04  | 0.29–1.89     |
| Intrusion (cm)  |               |               |       |      |               |
| 3–7             | .59           | 1.87          | <.01  | .19  | 18.47        |
| 8–14            | .01           | 5.66          | <.01  | 2.23 | 14.39        |
| 15–29           | .48           | 1.86          | .01   | .34  | 10.27        |
| 30+             | .01           | 125.80        | <.01  | 33.25| 475.97       |
| Weight (BMI)    |               |               |       |      |               |
| Under           | .06           | 2.62          | <.01  | 0.96 | 7.12         |
| Over            | .01           | 13.66         | <.01  | 3.70 | 50.42        |
| Obese           | .01           | 7.95          | <.01  | 2.88 | 21.64        |
| Extremely obese | .01           | 14.69         | <.01  | 4.41 | 48.95        |
| Males           |               |               |       |      |               |
| MY 2005–2014    | .10           | .57           | <.01  | .29  | 1.12         |
| Age 55+         | .62           | .80           | <.01  | .32  | 1.96         |
| Belted          | .20           | .53           | <.01  | .21  | 1.35         |
| Intrusion (cm)  |               |               |       |      |               |
| 3–7             | <.01          | 29.88         | <.01  | 16.46| 54.26        |
| 8–14            | <.01          | 44.02         | <.01  | 27.48| 70.50        |
| 15–29           | <.01          | 89.29         | <.01  | 39.49| 201.88       |
| 30+             | <.01          | 36.24         | <.01  | 18.92| 69.41        |
| Weight (BMI)    |               |               |       |      |               |
| Under           | .28           | .07           | <.01  | .02  | 2.93         |
| Over            | .10           | 1.74          | .01   | .90  | 3.38         |
| Obese           | .69           | 1.26          | <.01  | 0.40 | 3.95         |
| Extremely obese | .02           | 29.47         | <.01  | 1.85 | 468.40       |
Table 3. Weighted NASS analysis of drivers in frontal crashes. Outcome = Incidence of ankle injury.

| Parameter | MY 2005–2014 | MY 2006–2009 |
|-----------|--------------|--------------|
| Foot injuries | .37 | .27 |
| Ankle injuries | .31 | .23 |

**Females**

| Parameter | MY 2005–2014 | MY 2006–2009 |
|-----------|--------------|--------------|
| Weighted NASS analysis of drivers in frontal crashes. Outcome = Incidence of ankle injury. | .51 | .39 |
| Extravasation | 2.13 | 1.80 |
| Belted | .27 | .19 |
| Intrusion (cm) | .36 | .29 |
| Age 55+ | .38 | .31 |

**Males**

| Parameter | MY 2005–2014 | MY 2006–2009 |
|-----------|--------------|--------------|
| Weighted NASS analysis of drivers in frontal crashes. Outcome = Incidence of ankle injury. | .45 | .42 |
| Extravasation | 2.13 | 1.80 |
| Belted | .27 | .19 |
| Intrusion (cm) | .36 | .29 |
| Age 55+ | .38 | .31 |

reduction. Women were still at a higher risk for foot injury in the earlier MY vehicles. For MY 2005–2009, foot injuries occurred in 0.63% of female drivers and 0.40% of males; however, this gender difference was not nearly as apparent for MY 2010–2014 vehicles, where females (0.43%) were only 1.2 times as likely as males (0.36%) to sustain a foot injury.

Larger declines in ankle injuries were also observed in MY 2010–2014 compared to MY 2005–2009 (see Table 4), with only 0.16% of drivers incurring an ankle injury in more recent model years. There was an overall 49% reduction (0.32 vs. 0.16%, OR = 0.51, 95% CI, [0.20–1.28]), though it was not statistically significant. Among MY 2005–2009 vehicles, females (0.40%) were 1.7 times as likely as males (0.24%) to sustain an ankle injury. However, there was virtually no difference in the occurrence of ankle injuries for women relative to men in recent MY vehicles: women (0.16%) were no more likely than males (0.16%) to sustain an ankle injury in MY 2010–2014 vehicles. The decline in odds ratios of foot and ankle injuries, for women relative to men, is displayed for each MY group (MY 2001–2004, MY 2005–2009, and MY 2010–2014) in Figure 1. Further analyses of unweighted NASS-CDS data compared the incidence of injuries in men vs. women for specific foot and ankle bone fractures. As shown in Table 5 there were declines in medial and lateral malleolus injuries, primarily noted among women. However, for men there was a significant increase in talus injuries in newer MY vehicles, which was not apparent for women. It was not possible to determine whether there has been a decline in articular fractures, because that level of detail was only added to the AIS coding system in 2008 (Association for the Advancement of Automotive Medicine 2005).

Additional analyses of unweighted data on contact points indicated that, for both right-sided foot and ankle injuries, women were significantly more likely than men to make contact with the foot controls, including the brake (foot 49.3 vs. 36.4%, P = .01; ankle 52.3 vs. 33.9%, P = .002). However, contact

Table 4. Incidence of injuries in weighted NASS data. Passenger vehicle drivers in frontal crashes, MY 2010–2014 relative to 2005–2009.

| Fracture               | MY 2001–2004 | MY 2005–2009 |
|-----------------------|--------------|--------------|
| Tibia or fibula       | .23          | .24          |
| Talus                 | .62          | .90          |
| Tibial plateau        | .33          | .37          |
| Posterior malleolus   | .002         | .008         |
| Lateral malleolus     | .01          | .01          |
| Talus                 | .46          | .78          |
| Calcaneus             | .68          | .58          |

Table 5. Percentage comparison of specific fracture by model year group and gender (N = 19,174) a.

| Fracture               | MY 2001–2004 | MY 2005–2009 |
|-----------------------|--------------|--------------|
| Tibia or fibula       | .23          | .24          |
| Talus                 | .62          | .90          |
| Tibial plateau        | .33          | .37          |
| Posterior malleolus   | .002         | .008         |
| Lateral malleolus     | .01          | .01          |
| Talus                 | .46          | .78          |
| Calcaneus             | .68          | .58          |

aNS = Not statistically significant (i.e., P > .05).
with the floor (including toepan, console-mounted transmission lever, and console) was more likely to occur in right-sided foot and ankle injuries among men than women (foot 66.2 vs. 51.6%, \( P = .005 \); ankle 63.7 vs. 47.1%, \( P = .005 \); Table A4, see online supplement). No gender differences were noted for left feet.

Discussion

Ankle/foot injuries have declined significantly in newer vehicles, especially for women. Whereas before MY 2005 ankle and foot injury risk was markedly higher for women than men, risks for ankle injury are now virtually the same for both genders, and women are now only 1.2 times more likely than men to sustain a foot injury in a frontal crash. In contrast to the analyses conducted 20 years ago (Dischinger et al. 1995), height was not found to be a significant risk factor for ankle or foot injuries. As pointed out by Rudd (2009), the effect of gender seems to be related to more than just average height differences between men and women and could perhaps be due to a lower injury tolerance among female drivers or because of differences in foot size despite equivalent height. Although there were few men in the shortest height group in that study, they still had a risk of ankle/foot injury that was only one-sixth that of female occupants of a similar height (Rudd 2009).

It is apparent from the regression analyses that different risk factors have been identified for men vs. women. There was no association with MY for men, because greater declines in injury occurrence from older to newer vehicles were noted for women. Body weight, as determined by BMI, was a significant factor for both genders. For men it was a risk only among the extremely obese, whereas for women those who were overweight were at increased risk as well as those defined as extremely obese. However, the weighted mean BMI for men was also significantly greater than that for women (27.1 vs. 25.6, \( P < .001 \)). Body mass index is often used as an estimate of obesity, or excess adipose tissue, because it is easily derived from measures of weight and height. However, as previous studies have shown, BMI cannot be used as a comparable measure of fitness in men and women, because women have significantly greater amounts of total body fat, given an equivalent BMI (Gallagher et al. 1996). Previous studies have also shown an association between obesity and increased lower limb injury severity (Arbabi et al. 2003; Ye, Poplin, et al. 2015).

Age was found to be a risk factor for foot injuries in women, perhaps reflecting a difference in injury tolerance between men and women, as mentioned previously. This is in agreement with findings from Thomas and Bradford (1995), who found an increasing risk of lower limb injury among females older than 40, and Moran et al. (2003), who found an increasing risk of lower extremity fractures as occupants aged. Jibril et al. (1998) also noted an age effect only for women and only in the presence of intrusion. Karlson et al. (1998), using Crash Outcome Data Evaluation System data, found a higher incidence of ankle and foot injuries in women over the age of 60. However, Fildes et al. (1994) did not find age to be a risk factor for either ankle or foot injuries in men or women, though no adjustment was made for crash confounders in that analysis. Parenteau et al. (1996) noted that age was not as significant a factor as seating position. Crandall et al. (2012), in a similar analysis of NASS-CDS data, also found no association with age, but analyses were not stratified by gender.

Gender differences in risk remain for foot injuries, whereas the risk for ankle injuries is now essentially the same. This may be associated with the finding that, for both right-sided ankle and foot injuries, contact points for women are significantly greater for foot controls, including the brake, whereas for men contact with the floor was significantly greater. A study examining NHTSA standardized crash tests showed higher loads to the right tibia compared to the left, suggesting the possible significance of interaction with the pedal (Kuppa and Sieveka 1995). Because the current findings reveal that women are more likely to have foot pedals as the source of injury, perhaps seating position as well as anthropometry (foot size), or even footwear, may play a role in this gender difference; findings from the NHTSA study suggested that the loading of the lower limb could be more sensitive to the rate, peak, and onset of toepan intrusion than the absolute magnitude of the intrusion.

Toepan intrusion has been associated with lower extremity injuries in multiple studies (Austin 2012; Crandall et al. 1995; Eigen and Glassbrenner 2003; Rudd 2009). Although Rudd (2009) found that most frontal crashes occur with little or no toepan intrusion, and almost 70% of crashes resulting in leg, ankle, or foot injuries also occur with little or no toepan intrusion, risk generally increases with increasing levels of intrusion. In the current study, for both genders, toepan/instrument panel intrusion remains the biggest contributor to risk of ankle or foot injuries, significant for both men and women and both types of injuries, among frontal crashes with at least 8 cm of intrusion. It is not uncommon for change in velocity to be replaced by data on level of intrusion in analysis of crash-related injuries, due to both missing data and high correlations between the 2 crash factors (Austin 2012).

With regard to unweighted analysis of specific types of fractures, for the whole group there was a significant decline of bimalleolar and lateral malleolar fractures in newer MY vehicles (totals not shown), but this was primarily among women drivers. In contrast, a significant increase was noted for talus injuries among men (Table 5). Overall, with the exception of tibial plateau fractures, which are higher among men than women for both MY groups, women had a higher risk of injury for each specific fracture type.

Although BMI was shown to be a significant factor, its association with outcome varied with both gender and type of lower extremity injury. There may be great diversity among individuals within a BMI category because BMI is a ratio directly proportional to weight in kilograms and inversely proportional to the square of the height in meters. Drivers who are overweight may be at varying risks of injury, depending on whether they are short or tall. Studies have shown that men and women have different amounts of body fat for the same BMI and that the distribution of fat may also vary (Gallagher et al. 1996). As BMI increases, males tend to add visceral fat in the upper abdominal region, whereas females tend to add subcutaneous fat in the buttock and hip region. Such female pattern increases in subcutaneous fat to the hip and buttock region would increase occupant lap belt length and degrade a lap belt’s ability to restrain the bony pelvis/lower extremities in a frontal crash.

The risk associated with intrusion of the toepan and instrument panel may also be a function of occupant positioning. This
information, however, cannot be easily discerned from actual crash data. For instance, other possible areas to be explored would be seating position, because it frequently differs for men (average height 5’9”) vs. women (average height 5’4”); Centers for Disease Control 2012). In addition, though right-sided injuries are more common for both men and women, the source of injury for women is more likely to involve the brake or foot pedals, though for men the toepan is the more predominant source, even for intrusion as little as 3 to 7 cm. Crandall et al. (1996), using a driving simulator, found that an increased risk of injuries for smaller drivers with shorter feet may be associated with increased heel rise. This was also found in other studies by Pilkey et al. (1994) to increase the potential for foot and ankle injury. Volunteer braking behavior was also found to differ relative to the height of the driver. Taller drivers were more likely to maintain heel contact with the floor pan, pivoting between the brake and accelerator, whereas shorter drivers were more likely to lift the entire foot to move between controls (Parenteau et al. 2000).

Footwear was also indicated to be a factor in reducing the load transferred from an intruding footwell to the lower extremity. In particular, women’s high-heeled shoes were found to exhibit both static and dynamic instability, suggesting an increased risk for ankle injury (Crandall et al. 1996).

In summary, lower extremity injuries, especially ankle and foot injuries, remain a common cause of injury in frontal collisions. However, improvements in crashworthiness have apparently contributed to declines in these injuries for occupants of newer MY vehicles, especially women. Though the risk of ankle injuries is now essentially equal for men and women, there is still a higher risk of foot injury for women. Differences in body habitus relative to seating position may need to be considered to achieve further reductions in these disabling and costly injuries.

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