Published in final edited form as:
J Trauma. 2011 July ; 71(1): 217–222. doi:10.1097/TA.0b013e318208f874.

Mopeds and Scooters: Crash Outcomes in a High Traffic State

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Abstract

Background—Moped and scooter crash outcomes in the United States were last reported over 20 years ago. These vehicles have experienced resurgence in popularity with sales that have increased up to 60% in recent years. The purpose of this study is to identify risk factors between severe and non-severe driver related injuries and to identify modifiable risk factors.

Methods—The Florida Traffic Crash Records Database (FTCRD) was used to identify all crashes involving mopeds and scooters occurring between 2002 and 2008. A total of 5,660 moped crashes were evaluated. Multivariate logistic regression was used to determine the strength of association of severe injury for each risk factor.

Results—Over 90% of drivers involved in moped or scooter crashes were uninsured. Only 17% of all drivers wore helmets. Alcohol and drug use was a significant risk factor severe and lethal crashes OR 2.09, 95% CI (1.64, 2.66). Risk factors amenable for state intervention and associated with increased severe or lethal injury were unpaved roads OR 1.57, 95% CI (1.30, 1.88); driving speeds > 20 mph OR 2.02, 95% CI (1.73, 2.36); posted speed limits >30 mph OR 1.40, 95% CI (1.22, 1.62); major roadways with 4 or more lanes OR 1.83, 95% CI (1.04, 3.21); and poor lighting conditions OR 1.69, 95% CI (1.23, 2.32).

Conclusions—These results suggest that most of the traffic infrastructure does not accommodate the safety of moped and scooter drivers. Focused interventions and further investigation into statewide traffic rules may improve moped crash outcomes.

Keywords

Moped; Scooter; crash outcomes; Florida; traffic safety; traffic infrastructure; traffic laws; roadway conditions

Introduction

Scooters and mopeds are the major modes of transportation in many European and East Asian countries. In the United States, these vehicles gained only moderate popularity as

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Meetings: Florida Committee on Trauma 2009, Thirty-third Annual Shock Society Conference 2010

recreational vehicles in the 1970s and 1980s among urban dwellers and adolescents. With the recent downturn in the economy and fluctuating fuel prices, Americans have renewed their interest in mopeds and scooters as a major source of transportation. Averaging between 60 and 100 miles per gallon, estimates of moped and scooter sales have increased up to 60% in recent years.[1-4]

Mopeds are defined as a single-passenger two wheeled motorized vehicle with an automatic transmission and engine displacement less than or equal to 50cc.[5-12] The moped design has since evolved to include a two passenger version, often referred to as a scooter or mini-motorcycle, with an engine displacement up to 250cc.[11] Average speeds range from 30mph for small mopeds to 60mph for large scooters.

Reports published during the 1970s and 80s highlighted mopeds as a source of crashes and severe injuries, specifically head and lower extremity, among adolescents in the United States and abroad. [5, 6, 8, 10, 11, 13, 14] Research outside the United States reports a 20 times higher risk of injury associated with traveling by moped than by car.[5] To date, there are no contemporary studies that explore the factors contributing to moped crashes occurring in the United States. Given their increasing presence on U.S. roadways and anticipating their potential for worse crash outcomes, we believe that reexamining recent crash data on these vehicles will be important. The objectives of this study are: 1) to identify risk factors between severe and non-severe moped and scooter crashes and 2) to identify potential variables amenable for injury intervention. The state of Florida was studied because of its high traffic volume.

Materials and Methods

Data

The Florida Traffic Crash Records Database (FTCRD) was used to identify all crashes involving mopeds and scooters occurring between 2002 and 2008. This database is maintained by the Florida Department of Highway Safety and Motor Vehicles Office of Management Research and Development. The FTCRD contains driver demographics and crash related information obtained from law enforcement agency reports. Missing data represented 0.5-4% of overall data. Rubin's rules for multiple imputation over ten datasets was used to complete the missing data to derive the final analysis[15]. Demographic characteristics measured included age, gender, race, insurance status, driver license classification, moped ownership status, and crash location (rural or urban).

Outcomes and Risk Factors (exposure groups)

Severe-fatal injury was the primary outcome of interest. FTCRD defines severe injury as any sign of debilitation at the scene of the crash or any injury necessitating transfer to a higher level of care. Risk factors or exposures of interest included: Presence of protective equipment (helmet, eyewear), driving speed (mph), posted speed (mph), time of day, day of the week, alcohol and/or drug use, town type (college, university associated), county type (coastal or non-coastal), roadway, road surface type and condition, lighting conditions, weather, type of shoulder, number of lanes, and highway type (divided or undivided). A

college town was defined as any location in which the social and economic infrastructure of the community is dependent on the presence of the educational institution. University associated cities were those that contained at least one four year institution however their economic strength included other forms of major industry. The distinction between college and university town was made to account for student density to estimate eligible and young drivers. In this study, the terms mopeds and scooters are considered synonymous because the FTCRD does not distinguish between the two vehicle types.

Statistical Analysis

For the calculation of our point estimate, logistic regression was used because the outcome of severe or fatal injury is binary. The strength of association for each risk factor to our primary outcome was determined using univariate and multivariate logistic regression. Multivariate regression was then used to adjust and match for non modifiable factors that had the potential of confounding or biasing the outcome of interest. Confounders were considered in the multivariate analysis if it was reasonable to assume or if there was published data to show that these variables had an independent effect on the exposure (risk factor) and outcome of interest. Prior to regression analysis, multicolinearity was measured between the adjusted or confounding variables. None of the confounders in this study exhibited colinearity with each other. In the final multivariate regression, age, gender, and insurance status were treated as confounders. SAS version 9.1 for PC (Statistical Analysis Systems, Cary, NC) was used for all statistical analyses.

Results

Between 2002 and 2008 there were 5,660 moped crashes in the state of Florida. Of these crashes 18% resulted in severe or fatal injury. The demographic profile of moped drivers by injury status is shown in Table 1. The majority of crashes occurred in urban locations, severe cohort 64.6% and non severe 74.3%. Among those crashes occurring in rural areas 35.4% resulted in severe injury compared to 25.7% in the non severe injury group. Ownership status varied among moped drivers, with a greater proportion of severe injury crashes occurring among those who reported owning the vehicle, 55.7%. Moped drivers predominantly possessed a noncommercial driver's license; however, 30.8% of severe injury drivers and 23% of non-severe injury drivers were unlicensed.

Comparison of sociodemographic characteristics by severe and non-severe injury status are shown in Table 2. Only 17% of drivers were wearing a safety helmet at the time of the crash. The average driving speed for severe injury crashes was 25mph compared to 20mph for non severe injury crashes. Severe injury crashes occurred in areas with an average posted speed of 35mph. Most moped crashes occurred after 4pm. The percentage of severe injury crashes (33.4%) exceeded non severe injury crashes (28.4%) between 7:01pm and 6am. With respect to day of week, type of town, county location road surface type and condition the percentage of crashes occurring in the two cohorts was similar. More moped drivers involved in severe injury crashes were driving under the influence of drugs and/ or alcohol compared to those involved in non severe injury crashes, 11.6% and 5.4%, respectively. Poor lighting conditions also had a higher frequency of severe injury. While most moped

crashes occurred when the weather was clear, cloudy weather resulted in more severe injury crashes. Road type was also measured. More severe moped crashes occurred in areas with unpaved curbs and divided highways. The percentage of drivers involved in severe injury crashes increased as the number of lanes on the roadway exceeded three.

The crude and adjusted odds ratios (OR) for severe injury crashes are located in Table 3. The data was adjusted and matched for age, gender, and insurance status. The use of personal protective equipment did not significantly impact crash outcomes. Driving at speeds greater than 20 mph and on roads with a posted speed greater than 30 mph was associated with severe injury crashes adjusted OR 2.02, 95% CI (0.80, 1.13) and 1.4, 95% CI (1.22, 1.62), respectively. Alcohol and/or drug use increased the chance of a severe injury crash two-fold adjusted OR 2.09, 95% CI (1.64, 2.66). Town type and county location did not contribute to injury severity; however, traveling in rural areas was associated with severe injury crashes, adjusted OR 1.55, 95% CI (1.33, 1.80). Darkness and inadequate lighting conditions are associated with an increased risk of severe injury crashes, adjusted OR 1.69, 95% CI (1.23, 2.32) and 1.29, 95% CI (1.09, 1.53). Roadway conditions contributing to severe injury crashes include type of shoulder or curb, adjusted OR 1.22, 95% CI (1.02, 1.44); unpaved roads, adjusted OR 1.57, 95% CI (1.30, 1.88); four or more lanes, adjusted OR 1.84, 95% CI (1.04, 3.21); and divided highways, adjusted OR 1.21, 95% CI (1.04, 1.40).

Discussion

The last published research on crash outcomes in the United States for mopeds and scooters was over 20 years ago. The state of Florida is an ideal location to study the current trends of crash outcomes due to its high traffic density and the popularity of these vehicles among tourists and native residents[16]. The results of this study are also timely since there has been a substantial increase of moped and scooter purchases [1-4].

The risk of severe-fatal injury moped crashes is associated with several key factors. Demographically, people involved in severe injury crashes tended to be older than those involved in non severe injury crashes. The average age for moped crashes in this study was 38 years for severe injury and 34 years for non severe injury. This differs from earlier studies that showed mopedists between the age of 15 and 20 years accounted for a disproportionate share of deaths, accidents, and injuries.[10] The higher age may suggest a change in the use of these smaller vehicles, yet it may also be influenced by an older population in Florida where the average is 40.1 years, while the average age for the United States is 36.7 years.[17] Some of these age-related effects were accounted for through matching by age when comparing various risk factors.

Nearly half of those were involved in severe non severe injury crashes did not own the moped or scooter. This is a significant finding as Florida's coastal location and popularity as a tourist attraction have contributed to the large number of moped and scooter rental facilities throughout the state. The high frequency of crashes may be due to a population of drivers who are less likely to be familiar with the vehicle operation and the local traffic pattern. It is also not clear whether many of these rental facilities require insurance. Greater

than 90% of moped drivers in this study were uninsured. Florida law only requires operators of vehicles with at least four wheels to purchase personal injury protection and property damage liability insurance.[4] This difference in their insurance requirements highlights one of several discrepancies in society's and government's view of two-wheeled vehicles. As mentioned earlier, previous studies have suggested that the risk of crashing mopeds and motorcycles is higher than for cars. [18, 19] Based on the increasing trend of moped and scooter purchases and the disproportionate lack of insurance coverage, states that have loose requirements for insurance coverage may need to reexamine their policies.

Florida law requires moped drivers to possess a restricted operator or non commercial driver's license. Unlicensed drivers represented the most common characteristic involved in crashes in both cohorts (Table 1). In a tourist state such as Florida, one explanation is that moped laws vary from state to state. Nearby states such as North Carolina, Virginia, and West Virginia do not require moped operators to be licensed. Another explanation is that these drivers may represent underage drivers or those with suspended or revoked licenses. Lack of a valid license is associated with a higher risks of serious injury in the motorcycles literature.[20] Florida requires a valid license to operate a moped. Among those who had severe injury in moped and scooter crashes, 31% had no license compared to 23% in the less severe injury group. A countermeasure to the overwhelming percentage of unlicensed drivers would include proof of licensure at time of purchase.

Consistent with previous motor vehicle studies abused substances and driving speed independently had the strongest association with moped crash outcomes.[18, 19, 21, 22] Tougher penalties for DUIs and public awareness organizations have contributed to the national decline in alcohol related crashes and increased DUI convictions and license revocations.[21] In a study of adult motor vehicle crash victims presenting to Carolina Medical Center in Charlotte, NC between 1995 and 2002, Christmas et al found 39% of moped drivers were DUI of alcohol, which in their population was one-and-a-half times more than motorcycle or automobile drivers. Some of these drivers represented alcohol recidivism as many of them already had their licenses suspended or revoked.[23]

The standard moped has a maximum speed of 30-35mph. Operating a moped at speeds in excess of 20mph was associated with increased odds of severe/ fatal injury, OR 2.02, 95% CI (1.73, 2.36). This is further supported by the trend of less severe injury in colleges and university towns, as the speed limit on campus is typically 20 mph or less (Table 3). Traveling in areas with a posted speed >30mph was also associated with an increased risk of severe/fatal injury, OR 1.40, 95% CI (1.22, 1.62). Areas with higher speed limits are more likely to have larger and faster vehicles, which pose a risk to the moped or scooter driver. Roadway type also influenced outcomes. Riding a moped on a road with four or more lanes was associated with an increased risk of severe injury, OR 1.83, 95% CI (1.04, 3.21). This is a risk factor that has not been previously identified, but it is consistent with the other findings based on speed and exposure to larger vehicles. Mopeds and scooters may not be designed for most of the roadways that make up traffic infrastructure in the United States.

Environmental risk factors include cloudy weather, dark lighting conditions, presence of a curb or unpaved shoulders, traveling on divided highways and in rural areas. Of these the

absence of street lights, unpaved shoulders, and crashes occurring in rural areas were associated with the greatest risk of severe/fatal injury. This is consistent with previous findings where rural areas have classically been associated with an increased risk of traffic fatality compared to urban areas. [24] States may decrease driver injury by improving the quality of roads and placing more street illumination.

Helmet use has long been a point of controversy for operators of two-wheeled modes of transportation. In Florida mopedists sixteen years or older are not required to wear a helmet. Motorcyclists are required to wear helmets unless they are twenty-one years or older and have insurance with a minimum medical benefit coverage of $10,000.[4] Cars which have more physical protection than either mopeds or motorcycles have laws that require seatbelt use irrespective of age. The laws are not consistent in their protection of drivers of different vehicles. Previous studies show that nonhelmeted riders have an increased risk of serious injury and poorer hospital outcomes.[4, 8, 20] Since over 80% of drivers did not use helmets, this study was likely underpowered to find any significance.

There are several limitations to this project. Moped and scooter injury are relatively uncommon compared to car or motorcycle crashes. Thus as mentioned earlier, some exposures such as helmet use may be underpowered to find significance. Another limitation is the potential for misclassification from the data collection. This data may be biased due to subjective estimates of injury severity by Florida patrol officers and an ability to link the FTCRD with hospital records. We did address missing data by performing multiple imputations. Also, the number of nonfatal or serious moped crashes during the study period is likely underestimated as all crashes are not reported to law enforcement. Finally, given the retrospective nature of this study we are unable to report cause and effect and are limited to associations. Our findings, however, are consistent with previous investigations abroad.

In summary, mopeds share some of the same risk factors for severe injury and fatal crashes as do motorcycles and cars. However, there are factors that are unique to these vehicles and amenable to intervention such as requiring certain speed limits, limiting access to major roadways, and improving lighting conditions in rural and urban areas. These results suggest that most of the traffic infrastructure does not accommodate the safety of moped and scooter drivers. It is also concerning that at least 90% of all moped and scooter drivers did not have insurance. This may represent a significant future cost burden for the state especially as more people transition to this type of transportation. Finally, the recent increase in moped sales may represent a trend or possibly a paradigm shift in the use of these vehicles and our statewide traffic safety rules and regulations should reflect these changes.

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Table 1
Sociodemographic Profile Between Severe and Non-severe Injured Drivers

	Severe Injury (%) (n=1019)	*Non-severe injury (%)* (n=4641)
Average Age (yrs)	38	33.8
Gender		
Male	78.5	70.6
Female	21.5	24
Unknown	0	5.4
Race		
White	70.1	60.5
Black	13.8	18.8
Hispanic	14.7	13.4
Other	1.5	3.6
Unknown	0	3.8
Insurance Status		
Insured	7.3	9.9
Uninsured	92.7	90.1
Location		
Rural	35.4	25.7
Urban	64.6	74.3
Ownership Status		
Owner	55.7	46.8
Non-owner	44.3	53.2
Driver Licenses		
Class A	2.1	2
Class B	1.3	1
Class C	1.2	1.9
Class D/ Chauffeur	4	4.5
Class E/ Operator	57.6	56.7
Class E/ Restricted operator	2.6	3.3
None	30.8	23
Unknown	0.5	7.6

Driver License Classifications

Class A: Commercial motor vehicles – trucks or truck combinations with a gross vehicle weight rating (GVWR) of 26,001 lbs or more provided towed vehicle is more than 10, 000lbs

Class B: Commercial motor vehicles- straight trucks with a GVWR of 26,001 lbs or more.

Class C: Vehicles transporting placardable amounts of hazardous materials, or vehicles designed to transport more than 15 persons including the driver. GVWR of less than 26,001 lbs

Class D/ Chauffeur: Non commercial license, equivalent to Class E license (see below) required to drive a taxi, limo or other form of transportation for hire

Class E/ Operator: Any non-commercial motor vehicles with GVWR less than 26,001 lbs, including passenger cars, 15 passenger vans including the driver, trucks or recreational vehicles and two or three wheel motor vehicles 50cc or less.

Class E/ Restricted: Any vehicles listed under Class E operated by a person 15yrs of age, or person's learning to drive

Table 2
Risk Factors and their Crash Frequencies by Injury Type

	Severe Injury (%) **(n=1019)**	*Non-severe injury (%)* **(n=4641)**
Avg. Driving Speed (mph)	25	20
Avg. Posted Speed (mph)	35	30
Protective Equipment		
No Protection	80.5	74.9
Safety Helmet	17.6	17.2
Eye Protection	1.9	1.3
Unknown	0.1	6.7
Alcohol/ Drug Use		
Yes	11.6	5.4
No	88.4	94.6
Time of Day		
6:01am- 9:00am	5.3	6.1
9:01am- 12:00pm	10.4	11.1
12:01pm- 2:00pm	10.6	12.2
2:01pm- 4:00pm	14.6	15.6
4:01pm- 7:00pm	25.6	26.7
7:01pm- 11:00pm	20.3	18.5
11:01pm- 6:00am	13.1	9.9
Day of the week		
Monday	13.5	13.4
Tuesday	13.3	12.2
Wednesday	12.1	12.9
Thursday	15.4	14.7
Friday	15.4	16.9
Saturday	15.7	15.4
Sunday	14.6	14.5
Lighting conditions		
Dark (no light)	5.6	3.6
Dark (street light)	26	22.7
Dusk	3.2	4
Dawn	0.8	1
Daylight	64.5	68.8
Weather		
Cloudy	15.2	12.8
Rainy	3.8	5
Foggy	0.2	0.2
Clear	80.8	82
Town Classification		
College	2.3	4.2

	Severe Injury (%) **(n=1019)**	*Non-severe injury (%)* **(n=4641)**
University Associated	23.5	22.2
Other	74.3	73.6
County Location		
Coastal	89.3	88.6
Non-coastal	10.7	11.4
Roadway		
Off-roadway	85.3	84.8
On-roadway	14.7	15.2
Road surface type		
Slag/ Gravel/ Stone	4	4.3
Brick/ Block	0.1	0.6
Concrete	3.4	3.9
Dirt	1.3	1
Blacktop	91.2	90.1
Road surface condition		
Wet	6.8	8.2
Slippery	0.8	0.9
Icy	0.1	0.02
Dry	92.3	90.9
Type of Shoulder		
Curb	41.5	41.9
Paved	31.7	33.2
Unpaved	26.9	24.9
Highway type		
Divided	37.5	32.5
Undivided	62.5	67.5
Number of Lanes		
0	6.2	11.1
1	1.6	2.8
2	45.9	47.4
3	3.7	4
4	25.3	21.7
5	2.7	2.5
6	12.6	9.2
7	0.7	0.7
8	0.7	0.6
≥9	0.6	0.1

Table 3

Odds Ratio by Exposure Variable

	Odds Ratio	*Adjusted Odds Ratio**
Driving Speed (mph)		
>20	2.09, 95% CI (1.79, 2.42)	2.02, 95% CI (1.73, 2.36)
≤20	Reference	
Posted Speed (mph)		
>30	1.52, 95% CI (1.33, 1.74)	1.40, 95% CI (1.22, 1.62)
≤30	Reference	
Protective Equipment		
Safety Helmet	0.95, 95% CI (0.79, 1.14)	0.86, 95% CI (0.72, 1.04)
Eye Protection	1.38, 95% CI (0.82, 2.33)	1.29, 95% CI (0.76, 2.19)
No Protection	Reference	
Alcohol/ Drug Use		
Yes	2.29, 95% CI (1.81, 2.90)	2.09, 95% CI (1.64, 2.66)
No	Reference	
Time of Day		
6:01am- 4:00pm	0.95, 95% CI (0.80, 1.13)	0.90, 95% CI (0.76, 1.08)
7:01pm- 6:00am	1.19, 95% CI (1.00, 1.42)	1.19, 95% CI (0.99, 1.44)
4:01pm- 7:00pm	Reference	
Day of the week		
Monday	1.01, 95% CI (0.78, 1.30)	0.93, 95% CI (0.71, 1.21)
Tuesday	1.09 , 95% CI (0.84, 1.41)	1.05, 95% CI (0.81, 1.37)
Wednesday	0.94, 95% CI (0.72, 1.22)	0.93, 95% CI (0.71, 1.22)
Thursday	1.04, 95% CI (0.81, 1.33)	1.02, 95% CI (0.79, 1.32)
Friday	0.91, 95% CI (0.71, 1.17)	0.86, 95% CI (0.66, 1.44)
Saturday	1.02, 95% CI (0.80, 1.30)	1.01, 95% CI (0.78, 1.30)
Sunday	Reference	
Lighting conditions		
Dark (no light)	1.69, 95% CI (1.23, 2.31)	1.69, 95% CI (1.23, 2.32)
Dark (street light)	1.22, 95% CI (1.04, 1.43)	1.29, 95% CI (1.09, 1.53)
Dusk	0.84, 95% CI (0.57, 1.24)	0.98, 95% CI (0.66, 1.44)
Dawn	0.82, 95% CI (0.39, 1.75)	0.95, 95% CI (0.44, 2.04)
Daylight	Reference	
Weather		
Cloudy	1.21, 95% CI (1.00, 1.47)	1.25, 95% CI (1.02, 1.52)
Rainy	0.76, 95% CI (0.54, 1.08)	0.75, 95% CI (0.52, 1.08)
Foggy	1.03, 95% CI (0.22, 4.76)	0.97, 95% CI (0.21, 4.49)
Clear	Reference	
Town Classification		
College	0.54, 95% CI (0.35, 0.83)	0.64, 95% CI (0.41, 1.00)
University Associated	1.05, 95% CI (0.89, 1.23)	1.05, 95% CI (0.89, 1.24)

	Odds Ratio	*Adjusted Odds Ratio*[*]
Other	Reference	
County Location		
Coastal	1.07, 95% CI (0.86, 1.33)	1.01, 95% CI (0.80, 1.26)
Non-coastal	Reference	
Roadway		
Off-roadway	1.04, 95% CI (0.86, 1.26)	0.96, 95% CI (0.79, 1.17)
On-roadway	Reference	
Road surface type		
Slag/ Gravel/ Stone	0.91, 95% CI (0.64, 1.29)	0.88, 95% CI (0.61, 1.25)
Brick/ Block	0.16, 95% CI (0.02, 1.19)	0.24, 95% CI (0.03, 1.79)
Concrete	0.85, 95% CI (0.59, 1.24)	0.90, 95% CI (0.61, 1.33)
Dirt	1.30, 95% CI (0.70, 2.43)	1.51, 95% CI (0.80, 2.87)
Blacktop	Reference	
Road surface condition		
Wet	0.82, 95% CI (0.63, 1.29)	0.88, 95% CI (0.62, 1.07)
Slippery	0.88, 95% CI (0.41, 1.87)	0.84, 95% CI (0.39, 1.81)
Icy	4.48, 95% CI (0.28, 71.73)	4.28, 95% CI (0.27, 69.05)
Dry	Reference	
Type of Shoulder		
Curb	1.22, 95% CI (1.04, 1.45)	1.22, 95% CI (1.02, 1.44)
Unpaved	1.57, 95% CI (1.32, 1.88)	1.57, 95% CI (1.30, 1.88)
Paved	Reference	
Highway type		
Divided	1.25, 95% CI (1.08,1.44)	1.21, 95% CI (1.04, 1.40)
Undivided	Reference	
Number of Lanes		
0	0.98, 95% CI (0.55, 1.76)	1.00, 95% CI (0.55, 1.84)
2	1.71, 95% CI (1.01, 2.91)	1.62, 95% CI (0.93, 2.82)
3	1.64, 95% CI (0.88, 3.07)	1.52, 95% CI (0.80, 2.92)
4	2.06, 95% CI (1.20, 3.52)	1.83, 95% CI (1.04, 3.21)
5	1.92, 95% CI (0.99, 3.72)	1.53, 95% CI (0.76, 3.07)
6	2.43, 95% CI (1.39, 4.23)	2.11, 95% CI (1.18, 3.77)
7	1.70, 95% CI (0.65, 4.46)	1.44, 95% CI (0.67, 5.02)
8	2.00, 95% CI (0.75, 5.32)	1.83, 95% CI (0.67, 5.02)
≥9	11.96, 95% CI (3.05, 46.95)	10.06, 95% CI (2.51, 40.27)
1	Reference	

[*] Adjusted by age, gender, and insurance status