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Disentangling age–gender interactions associated with risks of fatal and non-fatal road traffic injuries in the Sultanate of Oman

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ABSTRACT

Objective Road traffic injuries (RTIs) are the leading cause of disability-adjusted life years lost in Oman, Saudi Arabia and United Arab Emirates. Injury prevention strategies often overlook the interaction of individual and behavioural risk factors in assessing the severity of RTI outcomes. We conducted a systematic investigation of the underlying interactive effects of age and gender on the severity of fatal and non-fatal RTI outcomes in the Sultanate of Oman.

Methods We used the Royal Oman Police national database of road traffic crashes for the period 2010–2014. Our study was based on 35 785 registered incidents: of these, 10.2% fatal injuries, 6.2% serious, 27.3% moderate, 37.3% mild injuries and 19% only vehicle damage but no human injuries. We applied a generalised ordered logit regression to estimate the effect of age and gender on RTI severity, controlling for risk behaviours, personal characteristics, vehicle, road, traffic, environment conditions and geographical location.

Results The most dominant group at risk of all types of RTIs was young male drivers. The probability of severe incapacitating injuries was the highest for drivers aged 25–29 (26.6%) years, whereas the probability of fatal injuries was the highest for those aged 20–24 (26.9%) years. Analysis of three-way interactions of age, gender and causes of crash show that overspeeding was the primary cause of different types of RTIs. In particular, the probability of fatal injuries among male drivers attributed to overspeeding ranged from 3%–6% for those aged 35 years and above to 13.4% and 17.7% for those aged 25–29 years and 20–24 years, respectively.

Conclusions The high burden of severe and fatal RTIs in Oman was primarily attributed to overspeed driving behaviour of young male drivers in the 20–29 years age range. Our findings highlight the critical need for designing early gender-sensitive road safety interventions targeting young male and female drivers.

Key questions

What is already known about this subject?

- We conducted a full review of a total of 128 selected papers on road injuries published in peer-reviewed journals since 1990 that included age, gender and road injuries in the abstract or title, mostly from western countries and 47 from the middle-eastern region including 15 papers published on Oman. We could not find any evidence of systematic analysis focused on age–gender interactions associated with road injury outcomes particularly in the Middle East and North Africa or the Gulf Cooperation Council countries.
- The existing studies on road injuries focus mainly on trends and behavioural risk factors, and a few include age and gender as control variables without systematically analysing their joint or interactive effects.

What are the new findings?

- In Oman, one in three of the road crash victims had a mild or moderate injury, and 1 in 10 had a fatal injury.
- The odds of severe incapacitating and fatal injuries are significantly higher for young male drivers than their older and female counterparts.
- Overspeed driving behaviour of young male drivers in the 20–29 years age range was the primary factor associated with severe and fatal road injuries in Oman.

Recommendations for policy

- The findings highlight the need for designing early gender-sensitive road safety interventions targeting young male and female drivers in Oman, and also elsewhere in other GCC countries with high burden of road injuries.
- Interventions promoting road safety awareness should focus on the broader social and human consequences of road crashes and related injury outcomes, with a focus on both native and expatriates particularly new drivers, families, educational institutions and work places.

INTRODUCTION

Globally, more than 1.2 million people die every year from road traffic injuries (RTIs), and between 20 and 50 million suffer non-fatal injuries and subsequent disability directly attributed to road traffic crashes.[1] In 2013, RTIs are ranked the seventh leading

cause of global disability-adjusted life years (DALYs) and leading cause of death for young people aged between 15 years and 30 years.[2] It is estimated that each year about 5% of gross domestic product in low-income and middle-income countries (LMICs) are lost to fatal and serious RTIs.[1] LMICs alone account for about 85% of road crash deaths and 90% of the DALYs.[1]

The countries in the Eastern Mediterranean region are an exception, which record a much higher death toll from road crashes than other world regions.[1] RTIs are the leading cause of DALYs lost in three Gulf Cooperation Council (GCC) countries: Saudi Arabia, Sultanate of Oman and United Arab Emirates.[2 3] Oman has the second highest death rate from road injuries within GCC.[1] In Oman, the years of life lost attributed to RTIs have increased by twofold from 11.8% in 1990 to 21% in 2010,[4] exerting significant burden on economy and healthcare resources. The increase in RTIs and associated mortality burden remain unprecedented since mid-1990s[5] while sustaining economic growth, rapid urbanisation, road infrastructure and a steady increase in motor vehicle use.[6] Between 1970 and 2015, the coverage of paved roads increased from 3 km to 31 071 km, whereas the number of registered motor vehicles increased from 1016 to 1 302 312 during the same period.[6 7] The rapid increase in private motor vehicles in Oman is partly due to limited availability of public transport services, especially in the capital city of Muscat, which holds more than a third of the total population. The population in Oman has also doubled in the last two decades, particularly the expatriate population representing 46% of the total population.[8]

In 2016, 4721 road traffic crashes were registered in Oman, of which 3261 were injuries and 692 were deaths.[7] About 44% of all crashes were due to vehicle collision mostly four wheelers, 24% collision with fixed objects, 17% overturn mostly attributed to speeding, 12% involved pedestrians and 3% of the crashes involved animals.[7] Motorbikes and bicycles accounted for approximately 2.4% and 2.8%, respectively, of all road crashes.[7] Among those had fatal outcomes, 28.5% were aged 16–25 years, 48% in the 26–50 years age range, mostly healthy, men and those driving the vehicle at the time of incident.[7] The high burden of mortality and disability has considerable economic, social and healthcare implications for the left-behind families, as these victims are usually the primary breadwinners. Overspeeding, overtaking, driver fatigue and collision between vehicles in non-signalled intersections and roundabouts were reported as the main causes of crashes.[9–11]

Road crashes occur as a result of a complex combination of risk factors such as drivers' behavioural and personal characteristics, time of the day, road geometry, vehicle, traffic, environmental and weather conditions.[12–15] Personal and behavioural risk factors, for example, lack of driving experience, violation of traffic rules, carelessness, fatigue, sleepiness, psychological stress, driving under the influence of alcohol, harmful and sedative drugs and using mobile phones while driving exacerbate the risks and the extent of crash injuries.[10 13–16]

Age and gender are critical risk factors associated with road traffic crashes and severity of RTI outcomes.[12 16 17] Young males are at higher risk of road traffic crashes and fatal outcomes than their female counterparts, mainly attributed to overspeeding, overtaking, aggressive attitudes, risky driving for fun and poor compliance of traffic rules and regulations.[1 17 18] However, in terms of the propensity of road crashes per mile driven, females generally have a slightly higher risk than males.[19] The exposure to road crashes also depends on the frequency of new driving licences issued each month.[20]

In Oman, the minimum legal age for holding a driving licence is 18 years for light vehicles and 21 years for heavy vehicles, although the traffic authorities can issue a licence at age 17 years under certain personal circumstances, for example, only if the driver is the sole breadwinner of the family and driving is an essential requirement for their employment.[21] The share of male licence holders is disproportionately high.[7] Overall, males are over-represented at all ages especially in the working ages.[22] This is attributed to high volume of male migration particularly from South Asia, and recent data show that non-Omani male expatriates have outnumbered their Omani counterparts.[22] Unlike Saudi Arabia, there is no gender discrimination for driving in Oman. Females represent about 20% of all driving licence holders and about 26% of the new licences issued in 2015.[8] Female workforce in Oman has also increased significantly from 57 815 to 130 077 between 2006 and 2015.[22]

There is a growing body of peer-reviewed literature on trends and behavioural characteristics associated with RTIs in Oman.[5 6 23–27] However, there is little systematic demographic analysis of how individual risk factors such as age and gender interact with each other and with other behavioural factors in determining RTI outcomes. We address this pertinent research gap by examining the underlying interactive effects of age and gender of road crash victims on the extent of severity of RTIs in Oman. We hypothesise that the risks of serious and fatal RTIs are the highest among young males than their older and female counterparts. Disentangling the age–gender interactions associated with RTIs will enable policy makers to identify and design appropriate behavioural interventions specific to certain high-risk groups.

Fatal road traffic crashes have become a routine public health emergency, and reducing the burden of RTIs is a national-level high priority policy agenda in Oman.[28] Most of the hospital deaths due to external causes are attributed to road crashes,[23] and increasingly a significant proportion of public and private funds is spent on managing, treating injuries and associated chronic physical and mental disorders.[24] Identifying primary level risk reduction strategies are therefore highly critical in reducing the burden of mortality and morbidity associated with road injuries. The need for evidence-based policy interventions was highlighted in the 2015 WHO

Global Status Report on Road Safety, which reiterated the plan of actions endorsed under the UN Decade of Action for Road Safety (2011–2020) declaration.[1] In addition, the recently introduced United Nations Sustainable Development Goal 3.6 aimed at halving the global road traffic deaths and injuries by 2020.[1]

METHODS

Data

We used the national database on road traffic crashes for the period 2010–2014, owned by the Royal Oman Police (ROP) and the National Centre for Statistics and Information. The database was made available for research use by The Research Council (TRC) of the Sultanate of Oman. TRC coordinates the National Road Safety Research Programme jointly with ROP, government ministries representing health, transport, regional municipalities, housing and social development sectors, the Muscat Municipality, Sultan Qaboos University and Petroleum Development Oman.[29]

The road traffic crash database is maintained and published by the Directorate of Road Traffic within ROP. The details of crashes are manually recorded in an Accident Report Form. The form includes information such as crash date, time, gender, age and nationality of drivers, type of injuries, fatalities, type and number of vehicles involved, cause of crash, type of collision, location, type of road, weather conditions and crash description along with a diagram and photographs of the crash.[30] A road traffic crash is defined as an incident involving human injury, damage to public property or a collision between vehicles where the concerned drivers fail to resolve the situation without the involvement of police officers.[23]

Our database had 35 851 registered road traffic crashes in anonymised format, collected between 1 January 2010 and 2 November 2014—the most recent data that the research team could access. The study was approved by the University of Southampton Research Ethics Committee. We carefully evaluated the data for potential inconsistencies and quality in terms of recording errors and incomplete information. We removed 66 records with inconsistencies and missing information (<0.2%). The final analysis considered 35 785 records for further investigation. Data on fatal outcomes refer to deaths recorded at the time of crash and any reported deaths until the closure of the case file in January of the following year.[21] There is no proper documentation on the criteria for classifying road injuries in Oman. We assume a fatal outcome as a death occurred at the time or within 30 days of the incident or after until the closure of the case file.[23] Severe injury refers to those involving more than one injury including bone fractures, permanent impairment of vision or hearing, severe burn and damage to organs.[31] Moderate injury refers to those involving injury but not incapacitating in nature, and mild injuries are those without requiring any emergency medical attention or hospitalisation. It has to be noted that the injury outcomes analysed in this paper refer to drivers, who are usually the person responsible for the crash. The cause of crash is determined on the basis of subjective assessment conducted by the police officer at the crash site.[32]

Statistical analysis

The outcome variable (Y) was the severity of RTIs defined in five mutually exclusive categories in an ordinal scale. Of the 35 785 incidents: no injury constituted 19%, mild (37.3%), moderate (27.3%), severe (6.2%) and fatal (10.2%). The recorded injuries may coexist with or without damage of vehicles, property or road infrastructure. We considered various statistical modelling options to examine the association between age and gender of the driver (primary predictors) on the severity of RTIs, controlling for relevant individual variables, risk behaviours, geographical location, vehicle, road, traffic and environment conditions.[14–16 23–27] The secondary predictor was the cause of crash with five categories: overspeeding, negligence, fatigue/wrong manoeuvre, alcohol drunk and non-human factors. Negligence is defined based on specific codes available in the crash dataset: carelessness, sudden stopping of the vehicle and lack of compliance in maintaining adequate safety distance. It has to be noted that overspeeding and drink driving could be associated with negligence. However, only the primary cause of the crash was recorded on the database. Other control variables included were: day and month of the crash as proxy to identify traffic congestion and festive season, type of road, type and number of vehicles involved, driver's nationality, governorate and year of crash.

A standard ordered logistic proportional odds model was considered appropriate for the statistical analysis.[13] However, the parallel lines or proportional odds assumption was violated in the Brant test.[33] To relax the proportional odds assumption and improve the estimation efficiency, a generalised ordered logit model was considered with both proportional odds and partial proportional odds, where the latter allows the coefficients to vary among the threshold of the outcome variable. The generalised ordered logit model can be written as:

$$P(y_i > j) = \frac{\exp\left(X_{1i}\beta_1 + X_{2j}\beta_{2j} - \phi_j\right)}{1 + \exp\left(X_{1i}\beta_1 + X_{2j}\beta_{2j} - \phi_j\right)} \quad \mathrm{j} = 1, 2, \ldots\ldots, \mathrm{M} - 1$$

where β_1 is a vector of parameters that meet the proportional odds assumption, and it is associated with a subset X_{1i} of the explanatory variables (risk factors), while β_{2j} is a vector of parameters that represents the partial proportional odds part of the generalised ordered logit model and associated with a subset X_{2j} of the explanatory variables. The outcome variable has five categories and hence four panels of coefficients are presented so that the coefficient of given variables is interpreted as 1 versus 2, 3, 4 and 5; 1 and 2 versus 3, 4 and 5 and so on. The higher the positive value of a coefficient, the more likely is the severity of RTIs, adjusting for the effect of other covariates.

To identify the most plausible risk factors associated with a given RTI outcome, we applied the Bayes' theorem to estimate model-based conditional probabilities of a risk factor (X), or a set of risk factors for a specific RTI outcome. After fitting the generalised ordered model, we estimated model-based conditional probabilities by applying the Bayesian theorem to examine the risk of RTIs for drivers in a specific age group for a given type of outcome:

$$P(X|Y) = \frac{P(Y|X)P(X)}{P(Y)}$$

For example, let X denote age group, then P(<20|fatal) represents the probability of a driver aged under 20 years at risk of a fatal injury, P(20–24|fatal) for those aged 20–24 years and so on. The estimated probabilities will allow us to identify the most important contributors to various RTI outcomes for targeted policy interventions. We used SPSS V.22.0 for data management and descriptive analysis and Stata V.13.0 for regression analysis.

RESULTS

The percentage distribution of severity of RTI outcomes by selected variables is presented in table 1. One in three of road crash victims had mild or moderate injury, and 1 in 10 had a fatal injury. Male drivers were twice as likely to cause fatal and severe injuries as females. The propensity for causing fatal injuries was the highest among males below 20 years and those aged 45–49 years. The propensity for severe injury was pronounced particularly among those aged below 20 years. The age–gender patterns associated with the severity of RTIs are illustrated graphically in figure 1. Most crashes were caused by young drivers aged between 20 years and 30 years, predominantly male drivers, whereas their females counterparts were mostly represented between ages 25 years and 30 years. Interestingly, a small minority of males involved in road injuries appeared to be driving illegally below age 18 years. There were only a few male drivers aged 60 years and above. Females were less likely to drive after age 40 years.

Overspeeding, fatigue and negligence were the three dominant causes of RTIs. However, the most common cause of fatal injuries was non-human factors (14.8%) and overspeeding (12.7%). Fatal injuries were common in crashes at both one-way and two-way roads, and in circumstances where a single vehicle was involved, bus and heavy vehicles such as lorry and trucks and during weekend and festive or holiday seasons (July–September). There was no uniform pattern of injuries across time. Note data for 2014 were incomplete and were available from 1 January to 2 November. Expatriate drivers from other Arab countries, Bangladesh and Pakistan, were at higher risk of fatal injuries. The variations in severe and fatal injuries were noticeable across governorates or regional headquarters. Wusta in the central region and Dhofar the southern and largest governorate recorded the worst in terms of fatal injuries. However, both severe and fatal injuries were the lowest in the most populous Muscat governorate.

Table 2 presents the coefficients and 95% CIs from the generalised ordered logit regression, controlling for primary and secondary predictors, and control variables. The probability of RTIs increased significantly towards severe and fatal outcomes for males, whereas female drivers had higher probability of being involved in the lowest threshold between mild and no injury. The age effects were marginally significant in most categories except for the below 20 years and 20–24 years age group. We interpret the results in table 2 in conjunction with adjusted conditional probabilities shown in table 3. The model-based conditional probabilities presented in table 3 clearly demonstrates evidence that the most dominant group at risk of all types of RTIs was young males. The probability of causing severe incapacitating injuries was the highest for drivers aged 25–29 (26.6%) years, whereas the probability of causing a fatal injury was the highest for those aged 20–24 (26.9%) years.

Overspeeding was the most dominant cause of crash for all types of RTIs, and it contributed relatively more to fatal injuries (67.1%). For example, the relative risk of fatal against no injuries was twice for overspeeding behaviour compared with that of fatigue and wrong manoeuvre, calculated as (67.1/14.3)/(52.0/22.6). For each of the other risk factor, the relative risk of fatal injuries was much heightened for crashes involving multiple vehicles, somewhat higher for crashes on one-way road, involving heavier vehicles (including bus and four wheelers), during July–December (festive, holiday and mild-winter season) and among Omani nationals.

Although the trends were not monotonic, the relative risk for fatal and severe injuries had increased from 2010 to 2014. The variations in RTIs were noticeable across governorates or regional headquarters: the severity of RTIs increased significantly in other governorates when compared with the most populous Muscat, particularly Wusta and Dhofar characterised by longer stretches of roads with higher speed limits and less traffic congestion. However, the relative risk of fatal injury against no injury was the highest in Muscat when compared with other governorates.

Finally, we examined the three-way interactions of risk factors: gender, age and cause of crash. Overspeeding featured as the leading cause of RTIs for most risk groups, especially among young males, followed by fatigue, wrong manoeuvre and negligence (table 4). For example, the proportion of fatal injuries among males that can be attributed to overspeeding ranged from 4%–6% for those aged below 20 years or above 34 years, to 13.4% for those aged 25–29 years and 17.7% for those aged 20–24 years. These were considerably higher than the other causes of crash for fatal injuries among males. Even for no injury crashes among males, overspeeding was the dominant cause across all age groups. There was no discernible pattern in the distribution of risk factors for female drivers. Nevertheless, overspeeding was also

Table 1 Unadjusted percentages of the severity of RTI outcomes by selected variables, Oman, 2010–2014

Variables	Severity of RTIs (%)					Total number of incidents
	No injury (n=6790)	Mild (n=13 346)	Moderate (n=9758)	Severe (n=2226)	Fatal (n=3665)	
All	19.0	37.3	27.3	6.2	10.2	35 785
Driver's gender						
Male	19.9	35.7	27.0	6.5	10.9	31 763
Female	11.9	49.3	29.6	4.1	5.1	4022
Driver's age (years)						
<20	13.9	37.4	28.2	8.2	12.3	2217
20–24	17.2	39.3	27.2	5.5	10.8	8631
25–29	19.5	36.8	28.0	6.7	9.0	8983
30–34	19.8	37.3	28.0	6.4	8.5	5848
35–39	19.5	35.5	27.7	6.4	10.9	3605
40–44	21.1	35.7	26.7	5.8	10.7	2379
45–49	21.9	35.5	23.9	5.1	13.6	1535
50+	21.0	37.3	24.7	5.7	11.3	2587
Cause of crash						
Overspeeding	19.9	34.0	26.5	6.9	12.7	19 757
Negligence	16.3	41.8	28.9	5.7	7.3	5567
Fatigue, wrong manoeuvre	14.7	44.3	29.6	5.5	5.9	8050
Alcohol	55.8	21.4	15.8	2.8	4.2	720
Non-human factor	21.9	34.8	24.0	4.5	14.8	1691
Type of road						
One-way	20.6	37.7	26.0	5.7	10.0	11 270
Two-way	18.2	37.1	27.9	6.5	10.3	24 515
No. of vehicles involved						
Single	24.3	30.7	26.7	6.6	11.7	19 531
Multiple	12.6	45.3	27.8	5.8	8.5	16 254
Type of vehicle						
Saloon	19.3	39.7	26.4	5.7	8.9	22 761
Four-wheel	19.1	34.5	26.6	6.4	13.4	4239
Pickup	18.8	34.0	29.1	6.8	11.3	3813
Bus	13.5	35.6	32.2	6.3	12.4	872
Heavy vehicle	18.1	30.5	30.3	8.3	12.8	4100
Day of the crash						
Weekday	19.2	37.7	27.2	6.2	9.7	25 517
Weekend	18.5	36.3	27.2	6.3	11.7	10 268
Month of the crash						
January–March	18.6	38.1	27.7	6.2	9.4	9400
April–June	20.5	36.8	27.1	6.1	9.5	9744
July–September	18.0	36.9	27.3	6.5	11.3	8958
October–December	18.6	37.4	26.9	6.2	10.9	7683
Year of the crash						
2010	26.0	33.3	25.3	6.1	9.3	7366
2011	17.7	37.1	27.3	7.1	10.8	7561
2012	18.3	39.4	26.1	5.4	10.8	8054

Continued

Table 1 Continued

Variables	Severity of RTIs (%)					Total number of incidents
	No injury (n=6790)	Mild (n=13 346)	Moderate (n=9758)	Severe (n=2226)	Fatal (n=3665)	
2013	18.6	38.70.000	27.2	5.8	9.7	7657
2014	12.3	37.9	31.8	7.2	10.8	5147
Driver's nationality						
Oman	18.2	38.1	27.6	6.2	9.9	29 292
India	25.7	35.1	24.1	5.6	9.5	2357
Bangladesh	12.4	31.3	31.8	9.5	15.0	814
Pakistan	23.2	31.6	25.0	6.8	13.4	1735
Arab	21.5	34.0	22.9	6.2	15.4	1021
Other	24.2	38.7	26.0	4.2	6.9	566
Governorate						
Muscat	23.0	42.1	26.4	3.8	4.7	12 491
Musandam	26.7	35.5	25.2	8.6	4.0	546
Dhofar	3.5	14.3	36.4	13.4	32.4	945
Dakhliya	17.4	39.9	26.2	6.4	10.1	5275
Sharqia	19.9	38.5	28.2	5.7	7.7	6739
Batina	12.9	28.0	30.1	10.0	19.0	5578
Dhahira	19.8	37.9	24.1	6.9	11.3	3729
Wusta	5.8	16.8	25.9	7.3	44.2	482

n is the number of registered incidents; row percentage sums to 100%.
RTI, road traffic injury.

the dominant cause for fatal and severe injuries for females particularly in the 25–29 years age group.

DISCUSSION

Road traffic crashes remain an unresolved global public health emergency in most LMICs. The risks of RTIs are considerably high in GCC countries including Oman where the oil-driven economy has overtime sparked rapid economic growth accompanied by large influx of expatriates, rapid urbanisation and unprecedented growth in motor vehicles. Our findings demonstrate evidence that the high burden of severe and fatal RTIs in Oman might be attributed to overspeed driving behaviour of particularly young males. The findings offer new insights to understanding the demographic influence of RTIs in Oman, where evidence-based interventions for road safety are critical to tackling the high burden of injuries.

The findings provide statistical evidence and confirm our research hypothesis that the odds of severe incapacitating and fatal injuries are significantly higher for young males than their older and female counterparts. In the event of causing a road crash with severe and fatal injuries, males aged 20–29 years represent the highest risk group. In comparison, females aged 25–29 years are more likely to be involved in mild and moderate injuries. Although fatal injuries are the highest among expatriate drivers from other Arab states, Bangladesh and Pakistan, the relative risk of fatal outcomes against no injury is much higher for Omani citizens. In geographic terms, fatal injuries are more likely in Wusta and Dhofar. The relative risk of fatal injury, however, is much higher in the most populous capital city of Muscat, which accommodates more than a third of total population in Oman.

Analysis of multiple risk factors demonstrates compelling evidence of overspeeding[21] as the primary cause of fatal and severe injuries especially among young males, significantly more than the other causes. There is also evidence of negligence and fatigue in drivers experiencing severe and fatal injuries. Although drink driving is uncommon in Oman, our database show that about 2% of the drivers had alcohol while driving the vehicle. According to the 2016 data released by the ROP, 53% of all road crashes (n=4721) were attributed to overspeeding and 4% overtaking, 15% each attributed to fatigue and neglect and violation of traffic rules, respectively, 7% not keeping required safety distance, 4% driving vehicles with mechanical defects, 1% road defects and less than 1% attributed to sudden stopping and weather conditions.[7] The high risk of fatal and severe injuries among young males exert considerable long-term impact on the left-behind families in terms of emotional, economic and social well-being. In addition, healthcare expenditure for managing disability and chronic conditions can be catastrophic for families and health systems in Oman. There is also an increase in female

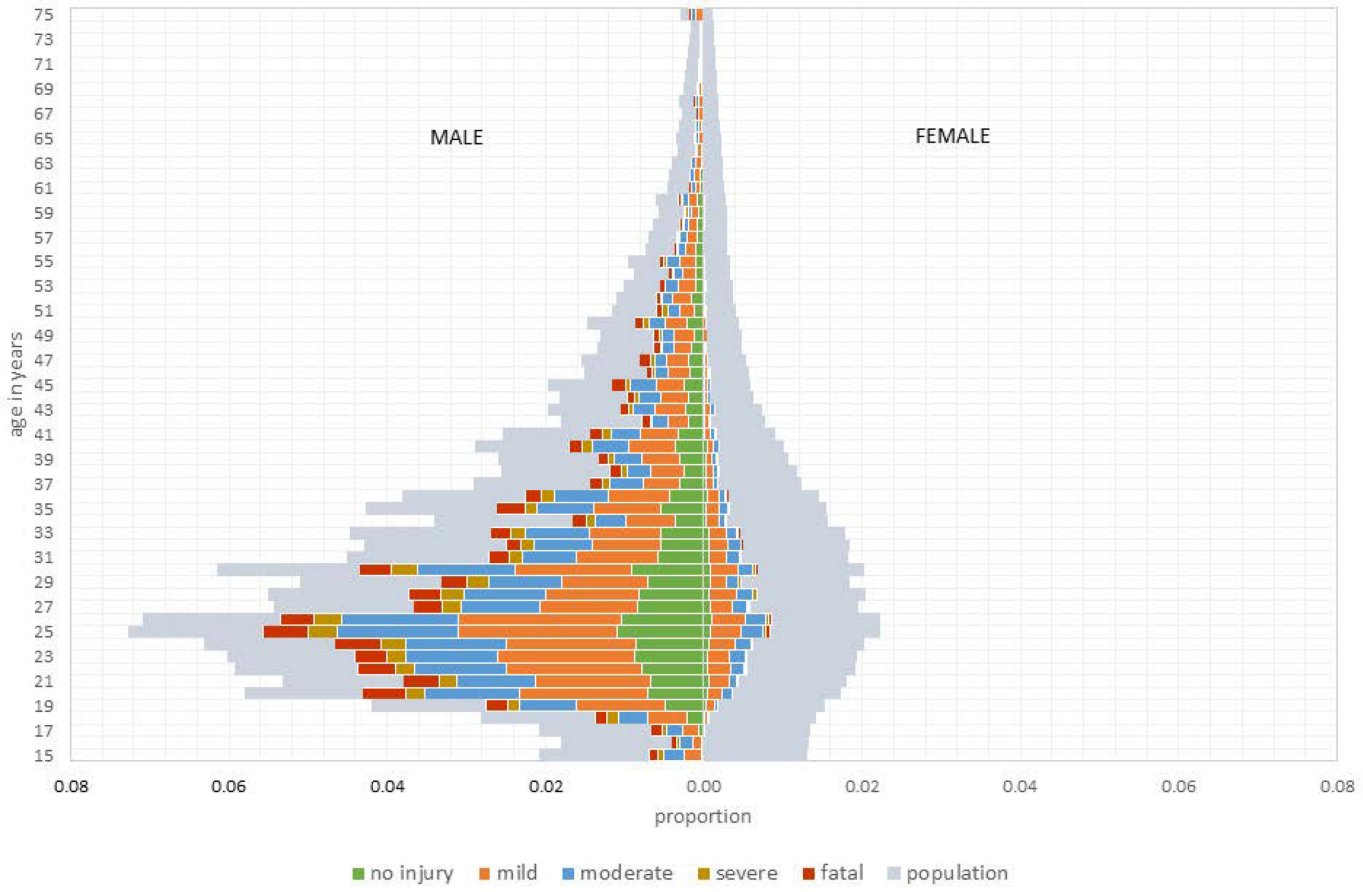

Figure 1 Age–gender distribution by severity of RTI outcome, Oman, 2010–2014. Based on data from the Royal Oman Police national database on road traffic crashes. The coloured bars represent the conditional probabilities of injury outcomes from road traffic crashes. The shaded grey area represents the distribution of population in each age (source US Census Bureau International Database; https://www.census.gov/population/international/data/idb/informationGateway.php, accessed 15 December 2016). Note the proportions of crash severity were not adjusted for the whole population.

drivers in Oman, which highlights the need to initiate early gender-sensitive interventions targeting young male and female drivers. Equally important is to strengthen the provision and use of public transport systems across Oman that can have measurable impact in reducing both traffic flows and crashes and other lifestyle-related chronic and non-communicable diseases. Our findings have implications for road safety policies and interventions elsewhere in the middle-east region especially the other high-income countries within GCC.[1 3]

Most of the deaths, injuries and disabilities attributed to road traffic crashes are preventable with proper evidence-based legislative and policy interventions. However, the design and implementation of road safety interventions are often complex in a multicultural and heterogeneous society such as Oman where the current trends in road traffic crashes are dissuading, particularly in terms of achieving target 3.6 of the UN Sustainable Development Goals.[1] About two-third of male population[8] in Oman are below age 25 years, which highlights the dire need for comprehensive targeted policies and multisectoral interventions and strict legislation to tackle road safety. Institution-based (school, college and workplace) and family-based interventions could focus on promoting awareness about road safety and the implications of road traffic crashes; countermeasures such as routine traffic surveillance especially for heavy vehicles, harsh penalty and licence restrictions for young drivers could reduce RTIs.[16 18] These interventions should also target the expatriate population, particularly new drivers from other LMICs who might not have adequate skills, knowledge about rules and regulations or driving experience in GCC countries.

The concerned authorities in Oman to whom our study recommendations apply include: the National Road Safety Committee established by the Royal Decree No.64/97 and headed by the Inspector General of Police and Customs and relevant members including the Directorate of Traffic, Ministries of Transport and Communication, Finance, Health, Housing, Social Development, Trade and Industry and Regional Municipalities.

It is important to highlight the data limitations of the present analysis. Unfortunately, we could not disentangle behavioural factors other than risky driving. Other useful information such as distance travelled, gender differences in the extent of overspeeding, driving experience, personal factors (eg, licence status, mobile phone use, stress, health

Table 2 Generalised ordered logit regression coefficients and 95% CIs of severity of RTIs

	Threshold between											
	No injury and mild injury			Mild and moderate injury			Moderate and severe injury			Severe and fatal injury		
Variables	β	95% CI	p Value	β	95% CI	p Value	β	95% CI	p Value	β	95% CI	p Value
Driver's gender												
Male (ref)	0.000			0.000			0.000			0.000		
Female	0.609	(0.506, 0.712)	0.000	−0.057	(−0.128, 0.014)	0.115	−0.431	(−0.546, −0.316)	0.000	−0.458	(−0.606, −0.312)	0.000
Driver's age												
<20	0.459	(0.308, 0.611)	0.000	0.192	(0.075, 0.309)	0.001	0.124	(−0.021, 0.268)	0.093	−0.027	(−0.198, 0.144)	0.755
20–24	0.197	(0.091, 0.304)	0.000	0.042	(−0.048, 0.132)	0.362	−0.076	(−0.188, 0.036)	0.185	−0.111	(−0.240, 0.017)	0.089
25–29	0.055	(−0.049, 0.158)	0.302	0.030	(−0.059, 0.119)	0.508	−0.203	(−0.314,−0.091)	0.000	−0.406	(−0.537, −0.276)	0.000
30–34	0.021	(−0.089, 0.131)	0.706	0.017	(−0.077, 0.111)	0.727	−0.236	(−0.356, −0.116)	0.000	−0.407	(−0.549, −0.266)	0.000
35–39	0.062	(−0.060, 0.183)	0.319	0.060	(−0.043, 0.163)	0.255	−0.152	(−0.282, −0.023)	0.021	−0.238	(−0.389, −0.087)	0.002
40–44	−0.009	(−0.142, 0.124)	0.892	0.035	(−0.079, 0.148)	0.549	−0.113	(−0.258, 0.032)	0.127	−0.162	(−0.331, 0.007)	0.060
45–49	0.013	(−0.104, 0.129)	0.830	0.013	(−0.104, 0.129)	0.830	0.013	(−0.104, 0.129)	0.830	0.013	(−0.104, 0.129)	0.830
50+ (ref)	0.000			0.000			0.000			0.000		
Cause of crash												
Over speeding (ref)	0.000			0.000			0.000			0.000		
Negligence	−0.068	(−0.152, 0. 016)	0.112	−0.147	(−0.211, −0.083)	0.000	−0.432	(−0.522, −0.342)	0.000	−0.551	(−0.664, −0.437)	0.000
Fatigue, wrong manoeuvre	−0.085	(−0.166, −0.005)	0.038	−0.163	(−0.224, −0.103)	0.000	−0.568	(−0.655, −0.482)	0.000	−0.759	(−0.871, −0.648)	0.000
Alcohol	−1.597	(−1.756, −1.438)	0.000	−1.088	(−1.266, −0.910)	0.000	−1.095	(−1.385, −0.805)	0.000	−1.114	(−1.482, −0.746)	0.000
Non-human factor	−0.095	(−0.218, 0. 028)	0.131	−0.297	(−0.402, −0.193)	0.000	−0.288	(−0.420, −0.156)	0.000	−0.138	(−0.286, 0.009	0.066
Type of road												
One-way (ref)	0.000			0.000			0.000			0.000		
Two-way	0.058	(−0.005, 0.121)	0.069	−0.022	(−0.073, 0.029)	0.393	−0.170	(−0.237, −0.102)	0.000	−0.230	(−0.312, −0.149)	0.000
Driver's nationality												
Oman (ref)	0.000			0.000			0.000			0.000		
India	−0.280	(−0.385, −0.176)	0.000	−0.209	(−0.302, −0.116)	0.000	−0.088	(−0.214, 0.037)	0.168	−0.078	(−0.230, 0.074)	0.313
Bangladesh	0.314	(0.184, 0.444)	0.000	0.314	(0.184, 0.444)	0.000	0.314	(0.184, 0.444)	0.000	0.314	(0.184, 0.444)	0.000
Pakistan	−0.309	(−0.434, −0.184)	0.000	−0.154	(−0.260, −0.047)	0.005	0.083	(−0.051, 0.216)	0.224	0.190	(0.031, 0.348)	0.019
Arab	−0.096	[−0.253, 0.061]	0.229	−0.005	[−0.137, 0.126]	0.937	0.205	(0.044, 0.366)	0.013	0.313	(0.132, 0.494)	0.001
Other	−0.221	(−0.377, −0.065)	0.006	−0.221	(−0.377, −0.065)	0.006	−0.221	(−0.377 , −0.065)	0.006	−0.221	(−0.377, −0.065)	0.006
Governorate												
Muscat (ref)	0.000			0.000			0.000			0.000		
Musandam	−0.148	[−0.347, 0. 051)	0.146	0.024	(−0.156, 0.204)	0.795	0.366	(0.104, 0.628)	0.006	−0.220	(−0.655, 0.215)	0.321
Dhofar	2.141	(2.011, 2.272)	0.000	2.141	(2.011, 2.272)	0.000	2.141	(2.011, 2.272)	0.000	2.141	(2.011, 2.272)	0.000

Continued

Table 2 Continued

	Threshold between											
	No injury and mild injury			Mild and moderate injury			Moderate and severe injury			Severe and fatal injury		
Variables	**β**	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**
Dakhliya	0.413	(0.327, 0.499)	0.000	0.295	(0.227, 0.364)	0.000	0.750	(0.653, 0.847)	0.000	0.819	(0.700, 0.938)	0.000
Sharqia	0.249	(0.167, 0.332)	0.000	0.210	(0.142, 0.278)	0.000	0.455	(0.355, 0.556)	0.000	0.489	(0.364, 0.614)	0.000
Batina	0.645	(0.554, 0.737)	0.000	0.944	(0.877, 1.011)	0.000	1.431	(1.346, 1.517)	0.000	1.514	(1.412, 1.616)	0.000
Dhahira	0.201	(0.106, 0.296)	0.000	0.230	(0.153, 0.308)	0.000	0.780	(0.674, 0.886)	0.000	0.838	(0.709, 0.967)	0.000
Wusta	1.889	(1.505, 2.272)	0.000	1.787	(1.567, 2.008)	0.000	2.349	(2.152, 2.545)	0.000	2.593	(2.388, 2.798)	0.000
Constant	0.232	(0.108, 0.356)	0.000	−0.785	(−0.895, −0.675)	0.000	−2.148	(−2.289, −2.007)	0.000	−2.661	(−2.826, −2.496)	0.000
No. of vehicles involved												
Single (ref)	0.000			0.000			0.000			0.000		
Multiple	0.899	(0.833, 0.966)	0.000	−0.028	(−0.077, 0.022)	0.272	−0.053	(−0.119, 0.012)	0.112	−0.027	(−0.106, 0.053)	0.510
Type of vehicle												
Saloon (ref)	0.000			0.000			0.000			0.000		
Four-wheel	0.014	(−0.071, 0.100)	0.742	0.178	(0.109, 0.246)	0.000	0.290	(0.203, 0.378)	0.000	0.350	(0.248, 0.452)	0.000
Pickup	0.025	(−0.066, 0.117)	0.590	0.186	(0.113, 0.259)	0.000	0.110	(0.015, 0.205)	0.023	0.094	(−0.020, 0.209)	0.107
Bus	0.400	(0.276, 0.525)	0.000	0.400	(0.276, 0.525)	0.000	0.400	(0.276, 0.525)	0.000	0.400	(0.276, 0.525)	0.000
Heavy vehicle	0.114	(0.021, 0.207)	0.016	0.392	(0.318, 0.465)	0.000	0.319	(0.225, 0.412)	0.000	0.265	(0.151, 0.379)	0.000
Day of the crash												
Weekday (ref)	0.000			0.000			0.000			0.000		
Weekend	0.108	(0.048, 0.168)	0.000	0.053	(0.005, 0.100)	0.030	0.087	(0.024, 0.149)	0.006	0.153	(0.079, 0.227)	0.000
Month of crash												
January–March	0.048	(−0.004, 0.100)	0.072	0.048	(−0.004, 0.100)	0.072	0.048	(−0.004, 0.100)	0.072	0.048	(−0.004, 0.100)	0.072
April–June (ref)	0.000			0.000			0.000			0.000		
July–September	0.121	(0.068, 0.174)	0.000	0.121	(0.068, 0.174)	0.000	0.121	(0.068, 0.174)	0.000	0.121	(0.068, 0.174)	0.000
October–December	0.147	(0.092, 0.203)	0.000	0.147	(0.092, 0.203)	0.000	0.147	(0.092, 0.203)	0.000	0.147	(0.092, 0.203)	0.000
Year of crash												
2010 (ref)	0.000			0.000			0.000			0.000		
2011	0.486	(0.406, 0.566)	0.000	0.208	(0.141, 0.275)	0.000	0.214	(0.126, 0.303)	0.000	0.185	(0.076, 0.295)	0.001
2012	0.411	(0.332, 0.491)	0.000	0.034	(−0.032, 0.101)	0.309	0.067	(−0.023, 0.156)	0.143	0.144	(0.036, 0.252)	0.009
2013	0.417	(0.337, 0.498)	0.000	0.059	(−0.008, 0.126)	0.086	0.170	(−0.074, 0.108)	0.717	0.058	(−0.053, 0.170)	0.303
2014	0.900	(0.799, 1.001)	0.000	0.348	(0.274, 0. 423)	0.000	0.226	(0.127, 0.324)	0.000	0.209	(0.089, 0.330)	0.001

Number of observations: 35 785; Log-likelihood: -–48 569.
RTIs, road traffic injuries.

Table 3 Adjusted probabilities showing the conditional distribution of risk factors for a given RTI outcome

	Severity of RTI				
Variables	**No injury**	**Mild**	**Moderate**	**Severe**	**Fatal**
Driver's gender					
Male	0.928	0.864	0.875	0.912	0.918
Female	0.072	0.136	0.126	0.088	0.078
Driver's age					
<20	0.047	0.064	0.062	0.077	0.073
20–24	0.223	0.250	0.236	0.224	0.266
25–29	0.259	0.249	0.257	0.269	0.216
30–34	0.172	0.161	0.168	0.165	0.140
35–39	0.103	0.099	0.104	0.096	0.100
40–44	0.071	0.064	0.065	0.061	0.070
45–49	0.046	0.042	0.039	0.040	0.052
50+	0.077	0.071	0.065	0.066	0.087
Cause of crash					
Overspeeding	0.520	0.537	0.539	0.602	0.671
Negligence	0.155	0.162	0.164	0.149	0.119
Fatigue, wrong manoeuvre	0.226	0.234	0.245	0.210	0.143
Alcohol	0.051	0.015	0.011	0.010	0.009
Collision with objects	0.048	0.053	0.041	0.033	0.051
Type of road					
One-way	0.324	0.308	0.300	0.321	0.361
Two-way	0.675	0.693	0.695	0.681	0.650
No. of vehicles involved					
Single	0.711	0.458	0.545	0.564	0.553
Multiple	0.294	0.540	0.454	0.436	0.450
Type of vehicle					
Saloon	0.648	0.668	0.612	0.597	0.587
Four-wheel	0.119	0.112	0.115	0.123	0.145
Pickup	0.107	0.101	0.114	0.110	0.107
Bus	0.018	0.023	0.027	0.029	0.031
Heavy vehicle	0.107	0.097	0.132	0.142	0.132
Day of crash					
Weekday	0.729	0.712	0.710	0.722	0.689
Weekend	0.270	0.289	0.287	0.280	0.315
Month of crash					
January–March	0.268	0.265	0.260	0.259	0.258
April–June	0.287	0.277	0.264	0.259	0.257
July–September	0.241	0.247	0.254	0.258	0.261
October–December	0.203	0.211	0.220	0.226	0.229
Year of crash					
2010	0.274	0.186	0.195	0.198	0.188
2011	0.196	0.206	0.215	0.243	0.224

Continued

Table 3 Continued

Variables	Severity of RTI				
	No injury	Mild	Moderate	Severe	Fatal
2012	0.222	0.238	0.212	0.203	0.231
2013	0.210	0.224	0.211	0.196	0.205
2014	0.096	0.147	0.164	0.164	0.156
Driver's nationality					
Oman	0.795	0.823	0.833	0.827	0.808
India	0.079	0.067	0.058	0.062	0.061
Bangladesh	0.017	0.021	0.026	0.028	0.029
Pakistan	0.058	0.047	0.041	0.044	0.055
Arab	0.030	0.028	0.026	0.028	0.037
Other	0.018	0.017	0.015	0.014	0.013
Governorate					
Muscat	0.426	0.383	0.345	0.221	0.169
Musandam	0.020	0.015	0.013	0.020	0.006
Dhofar	0.005	0.010	0.036	0.061	0.075
Dakhliya	0.131	0.159	0.139	0.154	0.150
Sharqia	0.191	0.201	0.190	0.166	0.143
Batina	0.116	0.114	0.173	0.244	0.285
Dhahira	0.109	0.108	0.091	0.113	0.108
Wusta	0.003	0.007	0.013	0.020	0.050

RTI, road traffic injury.

Table 4 Top ten conditional probabilities for each road injury outcome based on three-way interactions of age, gender and cause of crash

Age (in years)	Male					Female				
	No injury	Mild	Moderate	Severe	Fatal	No injury	Mild	Moderate	Severe	Fatal
<20		0.034	0.033	0.047	0.051			0.009		
20–24	0.117	0.046	0.046	0.040	0.031	0.007	0.015	0.014	0.010	0.012
	0.042	0.127	0.121	0.132	0.177	0.003	0.010	0.009	0.005	0.004
		0.033	0.032		0.027	0.005	0.006	0.005	0.003	0.002
25–29	0.127	0.117	0.124	0.151	0.134	0.011	0.021	0.021	0.017	0.013
	0.047	0.044	0.048	0.043		0.005	0.010	0.008	0.006	0.003
	0.035	0.033	0.035	0.033		0.004	0.007	0.006	0.004	0.002
30–34	0.079	0.071	0.076	0.087	0.082	0.008	0.015	0.015	0.011	0.009
	0.033		0.033			0.005	0.009		0.005	0.002
						0.002	0.004			
35–39	0.047	0.043	0.047	0.050	0.058	0.004	0.007	0.007	0.005	0.005
								0.004		
40–44	0.032			0.031	0.039				0.003	0.003
45–49					0.030					
50+	0.036	0.031		0.034	0.050					

Orange colour shading depicts overspeeding.
Green colour shading depicts: fatigue, wrong manoeuvre.
Blue colour shading depicts: negligence.
Note: Each column lists the top 10 conditional probabilities (not ranked in any particular order) related to specific RTI outcome.
RTI, road traffic injury.

conditions, previous incidents and type of profession) could help validate and improve our understanding of the risk behaviours. However, the present study could not explore these factors because of lack of data. Data on RTIs based on police judgement might be subject to bias and misclassification, although these records are verified by legal and insurance systems. For example, it is difficult to assess how fatigue and negligence are determined at the crash spot or later in the police investigations. Also, we could not analyse the influence of combination of risk factors such as overspeeding and negligence or drink driving because of lack of detailed (subjective) data. It is likely that some of the severe injuries could lead to fatal outcomes during or after hospitalisation, which could be potentially missed out in the ROP register. We could not explore the fatal and non-fatal injury outcomes of other passengers including children due to lack of data.

Despite these limitations, our study demonstrates systematic quantitative evidence of complex age–gender interactions associated with the severity of RTI outcomes. More importantly, the findings clearly pinpoint the importance and influence of age and gender in road crash analyses. It is recommended that future research should systematically address potential age–gender interactions in predicting risk behaviours associated with RTI outcomes.

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