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Exploring the risk factors of spinal cord injury in the causation of road traffic collisions in Saudi Arabia: A retrospective study (1970-2018)

Naif Khalaf Al-Shammari *

Mechanical Engineering Department, College of Engineering, University of Hail, Hail, Saudi Arabia

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ABSTRACT

Road traffic accidents (RTAs) are serious problems around the world. In this study, a retrospective analysis was conducted based on secondary data obtained from the Saudi official sources on RTAs, road injuries, and deaths, on people of all ages in the thirteen regions of the country during the period of 1970–2018. Moreover, comparison with the International Road Federation (IRF) statistics reports and the published literature has been made. This study aims to investigate, collate, and analyze data on the state of traffic safety in Saudi Arabia during the last five decades. It is believed that such a comprehensive review and analysis would help in a better understanding of the current traffic safety situation in this country and in developing strategies to improve this situation. A number of key issues were raised from this review. The study has shown that despite the sharp increase in the registered vehicles in Saudi Arabia, fatality rates (per vehicle) appear to have declined. However, these declines were accompanied by a persistent increase in the fatality rates per person. Frontal (56%) and side impacts (27%) are the common types of constituted RTAs. The portion of spinal injury per human body, including the neck, was found to be 11% exceeding the international rates (3-6%) because of reckless and aggressive driving (52.45%) in this country. The spinal injury occurs to one person injured every two hours, and 1:6 person injured on the roads. The leading cause of spinal cord injury (SCI) is a road traffic accident, accounting for 63% of all causes. Only 57% of all SCI casualties were received first aid at the site by emergency medical treatment (EMT), and the majority of casualties (49%) were reached by EMT service within 11-20 minutes. Most victims (63%) died at the spot before arrival at the hospital. It is obvious that there is a lack of emergency services and a shortage in the first aid coverage on highways of Saudi Arabia. The size of the problem of road crashes in Saudi Arabia, and the size of the human and economic resources lost is therefore enormous. Therefore, it is necessary to develop and implement an improved national strategy to mitigate this problem.

1. Introduction

The Kingdom of Saudi Arabia (KSA) is a country in Southwestern Asia that occupies approximately fourth-fifths of the Arabian Peninsula, with a total area of 2,250,000 square kilometers (MCI, 2008). The Saudi population has increased six times in the last four decades, reaching 31.7 million in 2016. This country experienced an oil boom over the same period that brought with it a significant increase in economic growth and living standards. It also resulted in a huge influx of expatriates who go there to work. Currently, those expatriates constitute 37% of the total population (GASTAT, 2018).

The economic prosperity experienced in Saudi Arabia led to dramatic changes to its road network and the number of motor vehicles. Asphalted road network length increased from 239 km in 1952 to approximately 64,632 km currently. The number of motor vehicles also increased exponentially from 145,000 in 1970 to almost 18 million currently, with approximately 800,000 vehicles being imported every year (GASTAT, 2018; MoI, 2018; MoT, 2018; WHO, 2015). This increase in living standards has also resulted in a large increase in the number of traffic crashes and, subsequently, in a tragic jump in

* Corresponding Author.
Email Address: naif.alshammari@uoh.edu.sa
https://doi.org/10.21833/ijaas.2020.10.006
Corresponding author's ORCID profile:
https://orcid.org/0000-0001-5100-267X

the number of deaths and injuries due to these crashes. Official statistics show that, on the average, more than nine thousand people get killed, and more than 38,000 get injured every year as a result of the approximately half a million traffic crashes that happen annually

In Saudi Arabia, several organizations and agencies are involved in road traffic and road safety like the General Directorate of Traffic (GDT), Ministry of Transportation (MoT), Ministry of Health (MoH), Saudi Red Crescent Society (SRCS), municipalities and others. GDT was established in 1960, under the Ministry of Interior (MoI), to be held responsible for traffic regulations and surveillance, driver education, vehicle testing, and motor vehicle collision reporting. Motor Vehicle Periodic Inspection Program (MVPI) has been in place since 1985, where each motor vehicle on the road is inspected annually in order to be roadworthy. Third-party insurance and seatbelt use for drivers and front-seat passengers were made compulsory in 2002 (GASTAT, 2018).

A recent comprehensive survey about road traffic accidents and injuries in Saudi Arabia is summarized by Mansuri et al. (2015). Barrimah et al. (2012) identified that high speed is the most common identified cause of RTA in Buraydah and Al-Qassim region of Saudi Arabia. Several outcome measures such as type of injury, deaths, police records, non-fatal injury were recorded. It was suggested that good surveillance and good quality of data is required. Khan et al. (2010) focused on the usage of seat belts in the southern Al-Aseer region. It was emphasized that most of the people do not use seat belts in the region, and more awareness is required. Al-Naami et al. (2010) reported that driver error is the major cause of RTAs in Saudi Arabia. It was also analyzed that due to a lack of trauma care centers in the country, deaths due to RTAs are more. Bendak (2005) also focused on seat belt utilization in the Riyadh region. It was suggested that stricter laws and fines should be implemented so that people will follow the safety rules while driving since many injuries are occurring due to non-compliance with seat belts and similar safety practices. Elshinnawey et al. (2008) studied the mortality records and statistical data analysis from the ministry of health of Saudi Arabia. It was recommended that there should be better healthcare education and facilities, especially for RTAs victims. Ansari et al. (2000) studied the general and specific causes of RTA's economic impacts. It was suggested that there is a huge direct and indirect economic loss because of RTAs. Moreover, it was recommended that a proper database for RTAs should be developed by using the data obtained from Al-Ahsaa hospitals and the traffic department. Qayed (1998) studied the various parameters of RTAs, such as type of injuries, deaths, number of vehicles, etc. Batouk et al. (1996) analyzed the number of dead people on arrival due to RTAs in the Al-Aseer region. It was reported that there is a shortage of emergency facilities which can handle such type of cases.

Contrarily, although Saudi Arabia, have significantly higher rates of morbidity and mortality as well as traumatic Spinal Cord Injuries (SCIs) due to RTAs, no attempt has so far been made to study the gravity of the problem caused by spinal injuries either on a regional or at the national level. An essential factor in the prevention, management, and analysis of traffic accidents is understanding the demographic characteristics of the victims of such accidents. So far, the epidemiology of spinal injuries in Saudi Arabia has not been studied. Furthermore, there is no national crashes database, and neuro-trauma centers serve as a database registry. This lack of data is an obstacle in analyzing such injuries and in developing measures that would mitigate those life-threatening injuries.

This study, therefore, represents an attempt to fill some of the gaps in the information related to the principal characteristics of spinal injuries of vehicle crashes in the Kingdom. It aims to develop a methodology to collect data on RTAs, study their main causes, to study causes of SCIs in RTAs, and to propose suitable engineering and management measures to minimize the existing consequences of spinal injuries in Saudi Arabia.

2. Literature review

In this research work, the literature review for contributing factors and consequences to road crashes in Saudi Arabia and is made and presented in the upcoming three sections. Moreover, statistical analysis is made based on the data obtained from various government organizations. The first section shows the contributing factors to road crashes reported in the literature. The second presents road crash characteristics reported in the literature. The last section presents the consequences of road crashes in Saudi Arabia based on official reports and the literature.

2.1. Contributing factors to road crashes

2.1.1. Demographic factors

Researchers have consistently pinpointed the effects of gender and age on risky driving behavior. Specifically, male younger drivers are reported in the literature to be consistently overrepresented in reckless driving and causing road traffic collisions. This finding is even more striking in Saudi Arabia due to the fact that women are prohibited from driving until 2018. This, together with the ever-increasing dependence on motor vehicles for transportation, lack of reliable public transport systems and a very large area of the country, has created great opportunities for expatriate driver positions (Deery, 1999). It was reported that expatriates are responsible for 40% of motor vehicle collisions in Saudi Arabia, although expatriates constitute one-third of the population (CDSI, 2010). This was mainly attributed to ignorance of local

driving regulations, the background of those expatriate drivers where most of them come from countries with high collision rates and aggressive driving behavior (Ansari et al., 2000). In addition, many of them come from countries where right-hand driving is practiced, and this is reported to create problems on the road and has the potential to cause crashes (Al-Naami et al., 2010; Ratrout, 2005).

The median age of the Saudi population is 26.7 years for men, indicating that the population of drivers is skewed toward the younger age range that is more likely to engage in risky driving behaviors (Sarma et al., 2013). Possible reasons for this over-representation of younger male drivers was the common belief among some of them that they always have the right of way and their unwillingness to yield to other drivers irrespective of the circumstances (Al Turki, 2014).

2.1.2. Drivers' behavior

The behavior of drivers is one of the crucial parameters to be considered in analyzing and understanding the causes of motor vehicle crashes. To understand the behavior of drivers, an assessment was done on the knowledge, attitudes, and practices related to driving of male students of the College of Health Sciences in Abha, Saudi Arabia. The sample size was 40 participants. Results revealed that more than half of the students were involved in crashes, that 22% of those had been injured, and 13% were admitted to hospital. Results also revealed that knowledge of road traffic regulations was moderate to high in more than 75% of those students, and more than 90% of them believed in the importance of using seat belts. Most of the responding students also revealed that they had problems with the use of seat belts, the most common of which were forgetfulness and anxiety (Al-Atawi and Saleh, 2013). In another study by Gharaibeh and Abdo (2011), a sample of drivers from Dammam, Al-Khobar, Qateef, and Jubail (cities on the Eastern coast of Saudi Arabia) was randomly selected to assess their knowledge and behavior in terms of traffic regulations and behavior on the road. The sample zie was 1007 participants. Results showed that 52% of the sample had been involved previously in road crashes, 75% were reportedly seat belt compliant, and 60% used mobile phones while driving. The authors concluded that drivers' knowledge regarding road traffic regulations and risks did not match their behavior. Alghnam et al. (2017) examined injury severity and associated mortality at a large trauma center before and after the implementation of the camera-based ticketing system. The results suggested positive health implications following the implementation of the camera ticketing system. It should be noted finally in terms of drivers' behavior that alcohol consumption is forbidden in Saudi Arabia. This makes driving under the influence of alcohol not a common cause of road traffic collisions in this country, unlike the USA, for example, where this behavior is responsible for one-third of all collisions (Aldawood et al., 2012).

2.1.3. Using electronic devices while driving

According to the World Statistics Pocketbook published by the United Nations General Assembly (UNGA, 2010), Saudi Arabia has 176.6 mobile subscriptions per 100 inhabitants, which is considered as one of the highest in the world. This means that almost all drivers have a mobile phone at their disposal while driving a motor vehicle. There are strong indications that mobile phone use while driving is a contributing factor to road traffic crashes in Saudi Arabia (Al-Naami et al., 2010). Alshammari et al. (2017) presented the type and contributing factors to RTAs in Arar, Northern Saudi Arabia. The results showed the following data; distraction habits while driving were as follows: 49.6% use the cellphone while they drive and 30.5% smoke.

Gharaibeh and Abdo (2011) examined traffic safety knowledge and compliance among high school and university students and found that 85% of study participants reported using mobile phones while driving. In another study, Osuagwu et al. (2013) found that making or receiving phone calls while driving was accompanied by seven times greater relative risk of road traffic injury involvement among drivers in Saudi Arabia than those who did not.

2.1.4. Seatbelt wearing rates

It is though not a cause of the accident but the cause of severe injury. One of the main contributors to increased severity of any crash is the non-use of protective devices in moving motor vehicles like seat belts (Bendak and Al-Saleh, 2013). It is well documented in the literature that failure to use seat belts is a major risk factor for vehicle occupants and that they are very effective in reducing the risk of injury in motor vehicle crashes. The most frequent and most serious injuries occurring in frontal impacts to occupants unrestrained by seat belts are to the head, neck, cervical region, and spine. Past studies have shown that seat belts significantly reduce the chance of death or serious injury in a crash (Cummins et al., 2011; Klair and Arfan, 2014).

Using seat belts for drivers and front-seat passengers was made compulsory in Saudi Arabia on 5 December 2000. Available data on wearing rate of seat belts for drivers before that date indicate a wearing rate of less than 3%. Moreover, children of less than six years of age were found to be more exposed to risk during vehicle collisions than other casualties in Saudi Arabia. This group constituted 7.2% of fatalities and 13% of injuries due to traffic crashes (Abbas et al., 2011). Results of the follow-up study, which also involved distributing a questionnaire to a sample of 1272 male drivers, indicated that older/more experienced, married, and better-educated drivers tend to wear their seat belts and ask their passengers to wear their seat belts more often than other groups of drivers.

Questionnaire results also indicated that self-reported seat belt wearing rates and asking front seat passengers to wear those expressed drivers' wishes, not their deeds. This is reflected by the much lower actual wearing rates than self-reported ones. This mismatch between belief and reality was also reported by Al Turki (2014), who found that 88% of drivers believe in the value of wearing seat belts, although only 2.9% wore them.

2.2. Road crash characteristics

In an effort to improve road safety, it is imperative to study and assess road crash characteristics. In this sub-section, the main road crash characteristics reported in official reports and the scientific literature are presented.

2.2.1. The overall distribution of RTA

The trend of young males affected more than females was mostly reported in all studies over the last 2.5 decades, with some variations in the type of estimates among regions, and period of reporting. The overall age-gender-adjusted rate for non-fatal RTAs was 20.7/100 persons/year. The rate for non-fatal RTA was found to be higher in the 10-19-year age group (Barrimah et al., 2012). An audit of RTAs over a one-year period revealed that 16% of the victims were less than ten years old, and 47% were between 11 and 30 years old. Males had a twice or greater incidence rate for RTA compared with females.

In another study, an even higher male to female ratio of 4:1 was reported and attributed to the driving laws in KSA. At the same time, 50% percent of road injuries among children were observed in pedestrians (Mansuri et al., 2015). The top regions in KSA regarding the occurrence of RTA were found to be Riyadh, Jeddah, Makkah, Madinah, and Qassim (Al-Naami et al., 2010). Few studies reported the time, season, or month of occurrence of an accident. A study conducted in Al-Ahsaa reported that 13.7% of accidents occurred during December (Jummada Thani), predominantly on the last three days of the week, while the lowest rate of 6.4% occurred during February. While in the Al Qassim region, the lowest rate of 5.8% was observed in March (Alghnam et al., 2014). Another study reported that Ramadan is the most common month for the accident that occurred during the first 12-24 hours (Memish et al., 2014).

Alshammari et al. (2017) found that the most frequent occurrences of RTAs were angle collision (40.8%), back collision (19.9%), hitting a fixed object (13.3%), and rest are frontal collisions.

2.2.2. Pedestrian crashes

More than one-quarter of all severe road crashes in Saudi Arabia involve pedestrians. This incurs a huge human and financial cost to society (Hassan, 2016). A detailed study involving the evaluation of 638 pedestrians–vehicle crashes in Saudi Arabia's capital city, Riyadh, found multiple injuries to be common in 79% of all severely injured victims. In 50% of the cases, the author reported multiple injuries specifically involving head, spine, and trunk. Results also revealed that 42% of all pedestrian victims have aged 15 years or younger, and the most serious risk factors for pedestrians were not paying attention and crossing a roadway (Al-Shammari et al., 2009).

2.2.3. Camel collisions

An important worldwide issue faced by governments, researchers, and health care professionals is the growing incidence of large animal-motor vehicle collisions. Globally, the most common large animals involved in motor vehicle collisions are kangaroos in Australia, camels in Saudi Arabia, and deer, moose, and bear in parts of Europe, Japan, United States and Canada (Grace et al., 2015; Lowry et al., 2013). However, the literature has shown wide experience among countries in dealing with the problem, but neither unique solutions nor consistent results have been found (Huijser et al., 2015). Large animal collision impacts produce a distinct pattern of injury than other motor vehicle collisions. In large animal collisions, there is a higher prevalence of injuries to the patient's head, neck, brain, and upper torso area (Lindenmayer and Likens, 2010). More than 700,000 camels graze freely in Saudi Arabia. Every camel crash is unique. Wild animals are very unpredictable and tend to appear suddenly. The speed at which the camel collides with oncoming vehicles, the size, and design of the vehicles are important factors in the severity of injury (Al-Shammari and Neal-Sturgess, 2016).

Ministry of Transportation (MoT) has applied some infrastructural measures over the past 30 years to prevent animal-vehicle collisions, including the construction of highway fencing and underpasses for camels. Consequently, the number of such collisions has dropped significantly in the last few decades, but this type of collision is still occurring. With each camel weighing up to 726 kg, any camel-motor vehicle collision is expected to yield catastrophic consequences to the vehicles involved and to their passengers. Therefore, more aggressive mitigation measures should be implemented to drop camel collision figures further (Al Shimemeri and Arabi, 2012).

2.3. Consequences of road crashes

There are many direct as well as indirect consequences of road crashes. Some of these crashes are listed and explained in this section.

2.3.1. Human losses due to road crashes

The biggest loss in road crashes is the loss of human life. Relying solely on police reports might

not reflect the full picture of human losses due to MVCs. In order to get a more comprehensive understanding of the extent of human losses in Saudi Arabia, Barrimah et al. (2012) incorporated health registration data on deaths due to traffic crashes. The findings of Barrimah et al. (2012) showed that deaths due to traffic crashes recorded in the Ministry of Health registration records are significantly more (sometimes more than double) than police-reported deaths. The authors added, based on the same Ministry of Health records, that road crashes cause 4.7% of all mortalities recorded in Saudi Arabia while they cause less than 1.7% of all mortalities in many developed countries like Australia, England, and America (Mahmoud, 2013).

2.3.2. Economic losses due to road crashes

In addition to human losses, road traffic crashes cause enormous economic losses. No accurate study has been conducted to determine economic loss due to traffic crashes in Saudi Arabia. All previous studies projected economic losses in developed countries (like the UK and USA) to estimate losses in Saudi Arabia. These estimates ranged from a minimum of US$0.53 billion to a maximum of US$16 billion. It is believed that these large discrepancies in loss estimates are caused mainly due to differences in the estimated average wage, medical costs, crash vehicle repairs, and others (Mohamed, 2015).

Post impact care is essential for reducing the severity of injury consequences once a road traffic crash occurs. In the case of major injuries, factors that can improve the chances of survivors towards recovery include actions (self-help) of the injured at the scene of the crash, help by bystanders, access to emergency facilities, the intervention provided by ambulance officers and paramedics at the scene and while being transported to the hospital, hospital trauma care and accessibility to rehabilitation services (Singh et al., 2014).

Post impact care has been identified to have some weaknesses in Saudi Arabia. The service coverage of emergency medical services and trauma care was found to be relatively weak and disorganized when compared to the corresponding service in developed countries with similar large land areas (Al-Naami.et al., 2010). Currently, transferring persons with traffic-related injuries to hospitals in Saudi Arabia should be officially done by the Saudi Red Crescent Society (SRCS) ambulances. Nevertheless, it is often reported in rural areas that many injured people are transported by medical practitioners with no experience in trauma care. Overall, it was reported that only 67% of road crash victims in the country were transported to hospital by ambulances, 25% by regular motor vehicles, and 8% by airlift (Mansuri et al., 2015). Moreover, it has been reported that a lack of organization, adequate equipment, and trained personnel are contributing to increased mortality due to motor vehicle crashes. All of these factors are suspected to be contributing to several avoidable mortalities due to RTAs (Almalki et al., 2011).

Although quite a lot of factors play an important role in the outcome of any road crash-related injury (like ambulance response time, road network length, availability of ambulances, etc.), the above-mentioned pre- and post-hospital admission death rates are considered high when compared to developed countries. Specifically, the ambulance response time has been identified in Riyadh to be below standards common in developed nations like the UK and the USA (Cripps et al., 2011). From the literature, it can be seen that all studies which investigated directly or indirectly the performance of the emergency rescue system in Saudi Arabia came to the conclusion that there is an imperative need to improve the quality of this system (Lee et al., 2014).

Interventional studies involving animals or humans and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

2.3.3. Medical consequences of RTAs in Saudi Arabia

Detailed and in-depth statistics for people with disabilities in Saudi Arabia do not exist. Yet, it has been indicated that road traffic crashes cause 12.1% of all urban and 14.8% of all rural disabilities in the country (Alghnam et al., 2014). Spinal cord injuries (SCI) are described as one of the most debilitating and costly injuries that anyone can suffer. Every year, around the world, between 250,000 and 500,000 people suffer SCI (Singh et al., 2014). The incidence of SCI varies from country to country and region to region. There is no reliable estimate of global prevalence, but the estimated annual global incidence is 40 to 80 cases per million populations (WHO, 2015).

A population study showed that the incidence of SCI in Saudi Arabia is high as 63 per million per year, which exceeded many countries worldwide. In particular, Saudi Arabia has recorded 81% of SCI resulted from RTAs in Saudi Arabia, which exceeded all previously reported values (Robert and Zamzami, 2013). It was also indicated that 16 percent of SCI in Saudi Arabia were quadriplegics, and 84% were paraplegics. The distribution of injury by etiology shows that RTAs were the cause of injury to all quadriplegics and to only 77% of the paraplegics (Al-Jadid, 2014). Moreover, it was reported that approximately 31% of all people and 76% of all accident-induced injuries transported by Saudi Red Crescent Society (SRCS) ambulances in 2016 were due to road crashes (SRCS, 2015). Upper and lower extremities represent the most common injuries (31-38%) due to MVCs in Saudi Arabia. Extremity injuries, although generally not life-threatening, are a major source of disability due to motor vehicle crashes. This is especially the case for fractures and dislocations involving the feet and ankles. Out of all those who are injured annually due to road crashes in Saudi Arabia, six to seven percent of them are discharged with residual disabilities (Alghnam et al., 2014). Almasri et al. (2015) presented a review of

the practice of maxillofacial trauma surgery in Makkah city. A total of 1132 patients' records were retrieved. Amongst, 965 maxillofacial injuries were included in the study as completed information was found. The maxillofacial injuries in Makkah city are mainly affecting male patients aged between 17-45 years old with the mandible and middle face fractures being most commonly injured, respectively.

Numerous trauma victims sustain abdominopelvic injuries, which are associated with considerable morbidity and mortality. Haddad et al. (2015) reported profile, outcomes, and predictors of mortality of patients with abdominopelvic trauma admitted to the intensive care unit (ICU) in a tertiary care trauma center in Riyadh, KSA. Of the 11,374 trauma patients who were admitted to the hospital during the study period, 2120 (18.6%) patients had abdominopelvic injuries, out of which 702 (33.1%) patients were admitted to the ICU. It was concluded that abdominopelvic injuries are common in trauma patients, affecting mainly young male victims.

Samman et al. (2018) studied the incidence and pattern of mandible fractures in the holy city of Madinah in the Kingdom of Saudi Arabia over a retrospective period of 3 years from 2013 to 2016. Moreover, the results were compared with other regions of the country. A total of 197 patients with fractures of the mandible were admitted in the period of the study by the Oral Maxillofacial Surgery Department, King Fahad Hospital, Madinah. There were 165 male and 32 female patients. The largest number of patients with trauma and mandible fracture was found in the age group between 16 and 30 years. Sonbol et al. (2018) identified the prevalence of femoral shaft fractures (FSFs) and studied the associated injuries among road traffic accident (RTA) adult victims in a Saudi trauma center in Madinah City. The study showed a high prevalence of associated injuries with FSFs among RTA victims.

Road traffic crashes were the direct cause of 73.6% of all cases of hemiplegia, paraplegia, and tetraplegia in the country. Furthermore, the head (22-35%), followed by the spine (5-9%), were the most common fatal injuries for road crash victims (Al-Naami et al., 2010).

The average stay of patients in Saudi hospitals is estimated to be 10-13 days (Alghnam et al., 2014). It was also reported that the total number of beds in 274 Ministry of Health hospitals spread across the country is 41,835 in 2015. At any given time, one-third of these beds are occupied by patients injured in road crashes (MoH, 1970-2018). This is in addition to the resources required at the scene of the crash and while being transported to the hospital, which also deprives the country of vital medical resources.

3. Data sources and limitations

The main source for this study was the various official reports published by local organizations in Saudi Arabia and international organizations that are directly related to road safety and the consequences of road crashes in Saudi Arabia. These were either searched for and downloaded from the internet or requested and obtained in printed form. A retrospective analysis was conducted, based on secondary data obtained from Saudi official reports on RTA injuries and deaths, on people of all ages in the thirteen districts of KSA during the period of 1970–2018. With the exception of minor RTAs like scratches (estimated to constitute 30% of all RTAs), virtually all tangible RTAs are included in annual statistical reports of the General Directorate of Traffic (GDT), Ministry of Interior (MoI), Saudi Red Crescent Society (SRCS) and Ministry of Health (MoH). This assertion for crash reporting is claimed by police and is achieved by enforcing, that required all vehicle repair establishments not to attend to any vehicle involved in a crash unless a police report on the crash is produced, with severe penalties for both drivers and establishments who fail to comply with this measure. These standards are believed to help in reducing under-reporting bias for RTA injuries and fatalities in the country to a minimum (MoI, 2018).

According to police sources, road traffic human loss is defined in KSA to include all traffic-related crashes that result in injury or death to road users (drivers, passengers, pedestrians, cyclists, and motorcyclists). RTAs injuries are defined to include all traffic-related non-fatal injuries. RTA fatalities are defined to include all traffic-related deaths that occur within 30 days from the accident.

Major contributing factors to RTAs in Saudi Arabia from police reports were analyzed, including speeding, careless driving, personal factors (e.g., fatigue, driving under the effect of medical drugs, alcohol, etc.), environmental and vehicle conditions. Moreover, details of the place of deaths and the burden costs of RTAs were analyzed based on the Arriyadh Strategic Traffic Safety Study conducted by the High Commission for the Development of Arriyadh (ADA, 2016).

Population denominator data between 1970 and 2018 were obtained from the Annual Statistical Book of the General Authority for Statistics (GASTAT, 2018), and the General Census of Population and Housing (CDSI) for the years 1974, 1992, 2004, and 2010. In particular, the population characteristics of Riyadh were obtained from the demographic studies reported by ADA. Length of paved and gravel roads was collected from Annual Reports of the Ministry of Transportation (MoT) while the number of annual registered vehicles in KSA and their technical faults were obtained from reports by GDT and Motor Vehicle Periodic Inspection Program (MVPI).

Annual crude rates of RTAs, RTA deaths and injuries per 1000 RTA (i.e., the ratio of injuries and fatalities to crashes), per 100,000 populations (ratio of injuries and fatalities to 100,000 population) and per 10,000 registered motor vehicles (the ratio of injuries and fatalities to 10,000 registered vehicles) were calculated to estimate the secular trends in the RTA problem in the country. The ongoing risk of

injury and death due to RTAs was also assessed using the odds ratio analysis, which is a commonly used technique in the analysis of crash severity data and relative risk (Agresti, 2002). Taking 1970 as a reference year, the odds ratios of fatalities among crash victims (injuries+fatalities) with 95% confidence intervals were computed for the years from 1970 to 2018.

RTC rates in Saudi Arabia were compared to international rates based on fatalities per capita (F/P), fatalities per 10,000 vehicles (F/V), and fatalities per one billion vehicle kilometers (F/VK). The overall mileage traveled by vehicles in Saudi Arabia was assessed based on the sampling models used by the Saudi Arabian Transportation Plan (SANTRAPLAN3). Data for comparison were obtained from the international road accidents databases such as The International Road Traffic and Accident Database (IRTAD), The Organization for Economic Co-operation and Development (OECD), The World Health Organization (WHO) Statistics and the annual world road statistic reports of The International Road Federation (IRF), as well as The United Nations (UN) and The United Nations Educational, Scientific and Cultural Organization (UNESCO) reports.

All statistical analysis was done using SPSS version 23. Tables and graphs were produced using Microsoft Excel 2010 and OriginPro release 2019 SR2.

4. Results analysis and discussions

This section gives an insight into the results obtained from the data collected from the various sources.

4.1. Historical growth and depth of the MVCs problem

In particular, Saudi Arabia has the distinction of being one of the most accident-prone countries of the world due to the fast increasing car and person ratio and a relatively young population. The prevalence of road traffic accident deaths and injuries is a global public health problem. RTA deaths are expected to increasefrom 1.25 million in 2013 to 2.4 million in 2030. The actual number of fatalities was conventionally calculated to have reached a total of 32.5 million by 2015 since the first injury crash was apparently sustained by a cyclist in New York City on 30 May 1896. In addition to these deaths, between 20 and 50 million suffer non-fatal injuries. In many parts of the world, this epidemic of road traffic injuries is still growing. It has been estimated that RTAs as a leading cause of death currently rank 9th and will rank 3rd by the year 2030 if left unabated (WHO, 2015).

Fig. 1 shows there has been a general downward trend in road traffic deaths in highly-motorized countries and Central and Eastern Europe during 2013. In contrast, fatality rates of RTAs have risen steadily in the MENA. In a recent report, data show that war (31%), followed by road traffic accidents (30%) are the main leading causes of injury deaths in MENA (WHO, 2015).

Although Saudi Arabia is regarded as a high-income developing nation, corresponding health and economic indicators rank the country among the affluent country (Fig. 2). In addition to the GCCs, Saudi Arabia has a high Gross national product (GNP) per capita in the world. The discovery of oil in 1933 has changed many aspects of life in the Kingdom.

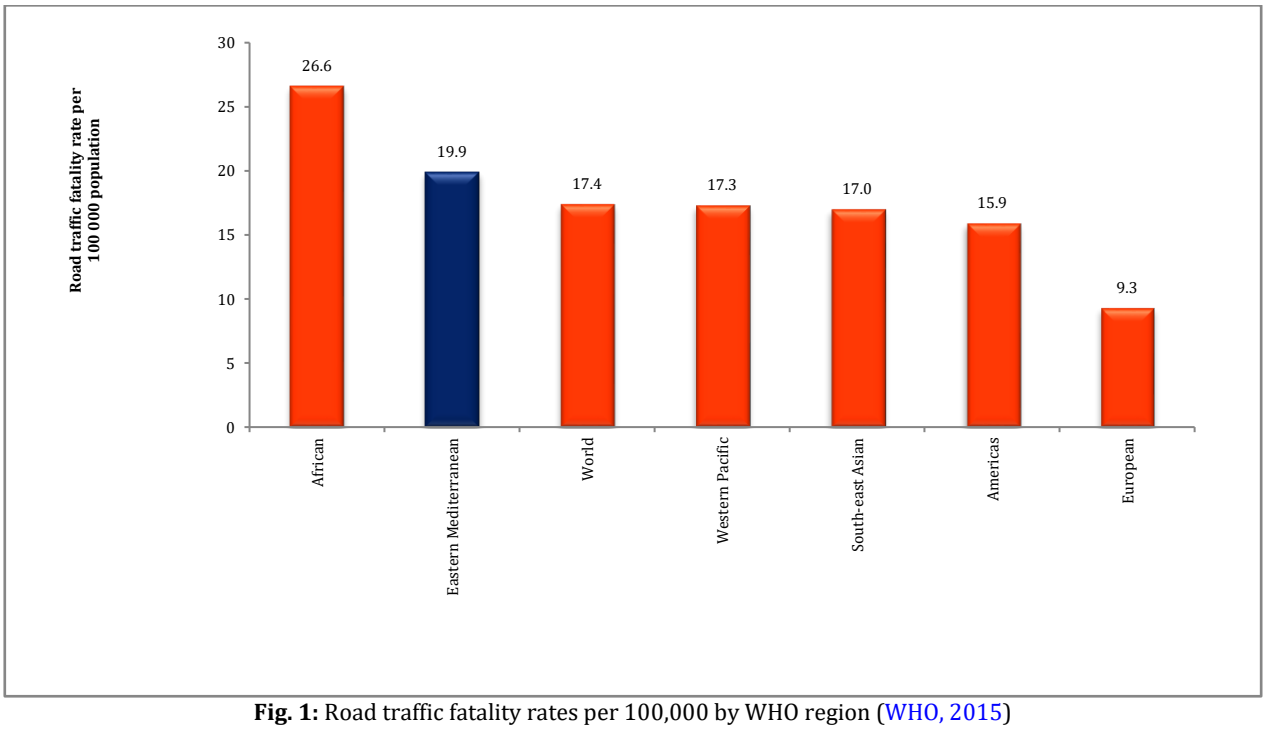

Fig. 1: Road traffic fatality rates per 100,000 by WHO region (WHO, 2015)

This resulted in a massive growth in the size of the population, the number of motor vehicles and roadway networks, and an increase of expatriates. This prosperity has demonstrated considerably in increasing the problem of road traffic accidents in Saudi Arabia made similar opinions regarding Gulf Countries, arguing that changes in cultures, habits, and attitudes can create safety-related problems on the road (Mansuri et al., 2015).

In this work, a retrospective analysis was conducted on the impacts of road traffic accidents in Saudi Arabia. Historical data related to MVCs between 1970 and 2016 were collected and collated from annual traffic reports produced by the General Directorate of Traffic-Ministry of Interior (MoI, 2018), annual reports produced by the Ministry of Health (MoH, 2018) and annual reports produced by the General Authority of Statistics (GASTAT, 2018).

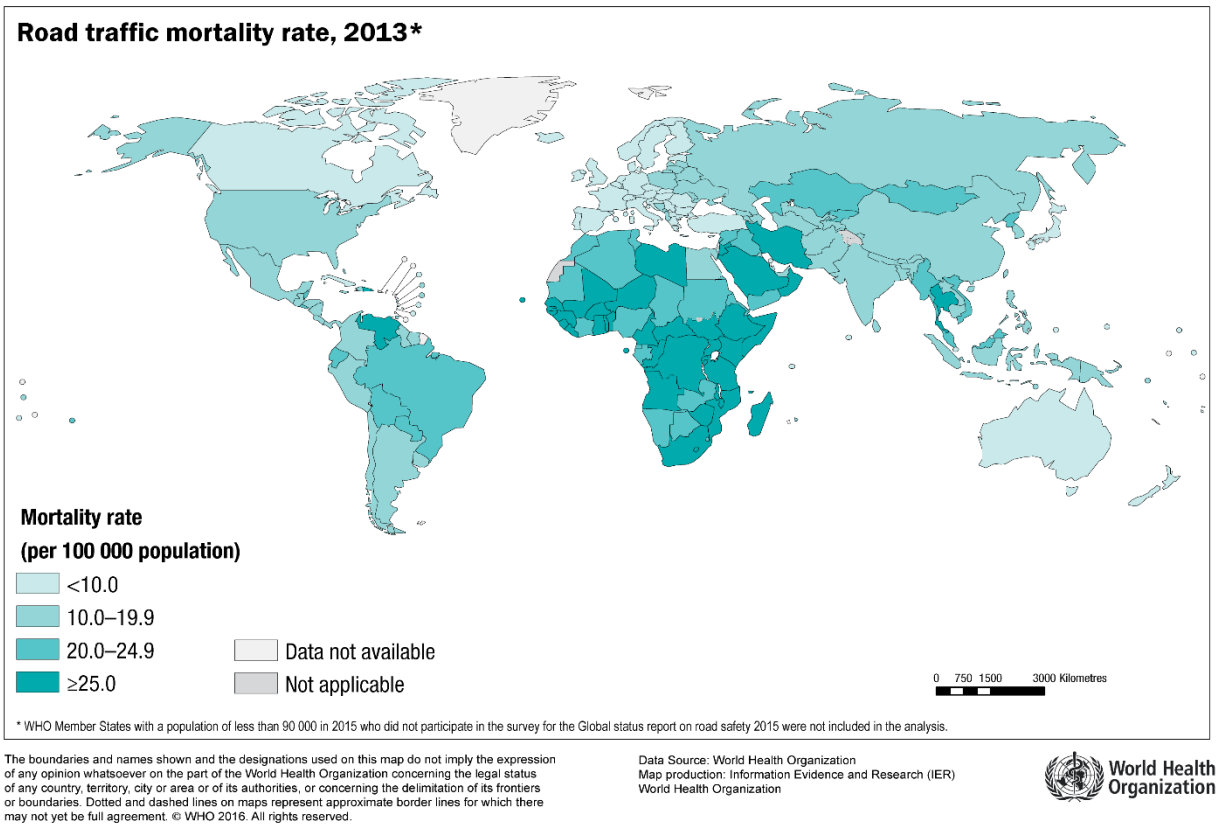

Fig. 2: Global mortality rates from RTAs for the Year 2013 (Mansuri et al., 2015)

The results revealed that there had been a continuous increase in the number of RTAs, injuries, and fatalities during the past five decades. Also, it was estimated that one million persons died or were seriously injured in road traffic accidents since 1970, a figure equivalent to 4.42 % of the total population of Saudi Arabia in 2018.

Data on the population, number of registered vehicles, length of the road network and number of crashes, and the resulting injuries and deaths are presented in Table 1. It should be noted that in Saudi Arabia, any crash involving a motor vehicle should be reported to traffic police by law. Moreover, motor vehicle panel beating and repair centers are not allowed to start any repairs on any motor vehicle without a police report that clearly gives them permission to repair that specific motor vehicle. Traffic authorities also put severe penalties for both drivers and repair centers who fail to comply with the law. By enforcing this law, traffic authorities ensure that all crash-related statistics are collected and entered on a national database and that theft and illegal alterations to motor vehicles are kept to a minimum.

Between 1970 and 2018, the Saudi population increased at an annual average growth rate of 3.81% (GASTAT, 2018). The highest rate, 4.85%, was achieved during the 1970s and 1980s of the twentieth century due to the influx of expatriate workers to the country following the boom in oil prices. Likewise, the number of registered motor vehicles increased at an average growth rate of 11.24% per year during the 1970s and 6-10% between 1980 and 2018 (MoH, 2018). Similarly, the length of paved and gravel roads has also increased by nearly 8 folds (8,500-64,632 km) and 43 folds (3,487-145,132 km), respectively (MoT, 2018). These increases are illustrated in Fig. 3.

The lifestyle of the people of Saudi Arabia has changed markedly since 1970, following the rapid economic growth due to the oil boom. Fig. 4 shows growth in the population and in the number of registered motor vehicles. The number of traffic crashes and the resulting deaths and injuries is also

shown in the same graph. The annual increase of road network length is shown in Fig. 5.

Table 1: Vital statistics related to MVCs in Saudi Arabia in 1970-2018

Year	Population	Registered Vehicles	Roads		MVCs		
			Paved	Gravel	Crashes	Deaths	Injuries
1970	5,745	145	8,334	3,487	9,123	570	5,483
1971	6,071	180	8,888	4,174	13,314	834	6,530
1972	6,323	243	9,244	4,963	22,656	1,058	7,901
1973	6,587	355	9,852	5,743	25,499	1,154	8,771
1974	7,009	514	10,801	6,770	31,801	1,594	10,532
1975	7,331	774	12,005	8,510	45,242	1,975	11,606
1976	7,670	1,113	13,817	11,193	50,670	2,032	11,413
1977	8,028	1,433	15,617	13,307	62,095	2,378	14,824
1978	8,406	1,723	17,646	16,948	61,568	2,871	16,832
1979	8,806	2,069	19,227	20,119	70,155	2,731	16,218
1980	9,229	2,468	20,474	24,186	65,503	2,427	15,872
1981	9,677	3,019	21,201	28,978	72,350	2,953	18,616
1982	10,152	3,569	21,841	33,310	79,193	3,499	21,475
1983	10,656	3,920	23,146	38,644	91,058	3,338	22,850
1984	11,191	4,144	24,455	46,836	80,765	3,277	22,630
1985	11,759	4,281	25,682	52,226	72,528	2,703	22,602
1986	12,363	4,428	26,377	57,502	73,335	2,814	23,723
1987	13,006	4,574	26,982	61,500	75,921	2,585	23,059
1988	13,692	4,768	27,808	63,905	85,071	2,647	23,278
1989	14,422	4,950	28,660	66,403	88,424	2,697	23,526
1990	15,202	5,117	29,537	69,000	87,248	3,232	25,516
1991	16,035	5,329	30,442	71,698	83,645	3,495	27,385
1992	16,948	5,588	31,374	74,501	82,386	5,982	34,441
1993	17,366	5,862	32,335	77,414	121,654	5,883	35,884
1994	17,794	6,111	33,326	80,441	124,782	6,358	36,025
1995	18,232	6,334	34,346	83,586	174,738	3,123	26,115
1996	18,681	6,580	35,399	86,854	147,776	3,131	25,078
1997	19,141	7,046	36,483	90,250	174,214	3,474	28,144
1998	19,613	7,554	37,601	93,779	289,788	4,290	31,059
1999	20,096	8,049	38,753	97,446	296,013	4,848	32,361
2000	20,591	8,467	40,202	101,256	308,249	4,419	28,998
2001	21,098	9,009	41,468	105,215	330,322	3,913	28,379
2002	21,618	9,485	42,616	109,329	247,593	4,161	28,372
2003	22,151	9,947	43,120	113,604	281,885	4,293	30,439
2004	22,674	10,386	44,276	115,046	311,094	5,168	34,811
2005	23,256	10,928	44,986	118,567	314,857	5,982	34,441
2006	23,829	11,515	47,699	121,110	305,426	5,883	35,884
2007	23,981	12,121	52,302	125,441	458,880	6,358	36,025
2008	25,790	12,786	53,947	127,619	485,931	6,458	36,489
2009	26,660	13,447	54,974	130,736	484,805	6,142	34,605
2010	27,560	14,145	58,036	132,585	498,203	6,596	38,595
2011	28,570	14,842	59,143	136,831	544,179	7,153	39,160
2012	29,200	15,626	60,336	138,846	589,258	7,638	41,086
2013	29,990	16,601	61,376	140,870	526,429	7,661	37,530
2014	30,770	17,523	62,735	142,464	478,450	7,486	35,843
2015	31,520	18,554	64,412	144,152	518,795	8,063	36,302
2016	31,740	19,511	64,632	145,132	533,380	9,031	38,120
2017	32,552	20,906	65,964	145,132	460,488	7,489	33,199
2018	33,413	22,324	67,027	145,132	352,464	6,025	30,217

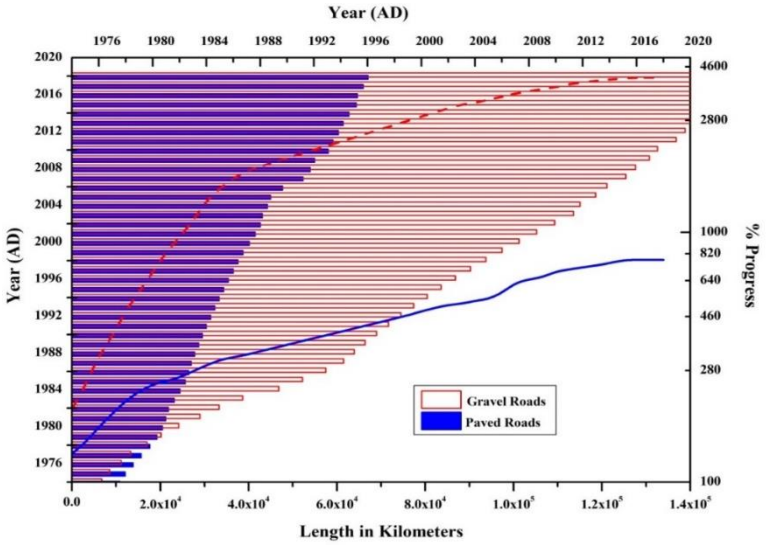

Fig. 3: Asphalted and gravel roads in Saudi Arabia 1970-2018

Fig. 6 shows the change, in percentage terms, of rates of crashes, deaths, and injuries per person and per vehicle. Fig. 4, Fig. 5, and Fig. 6 were derived from official statistics given in Table 1.

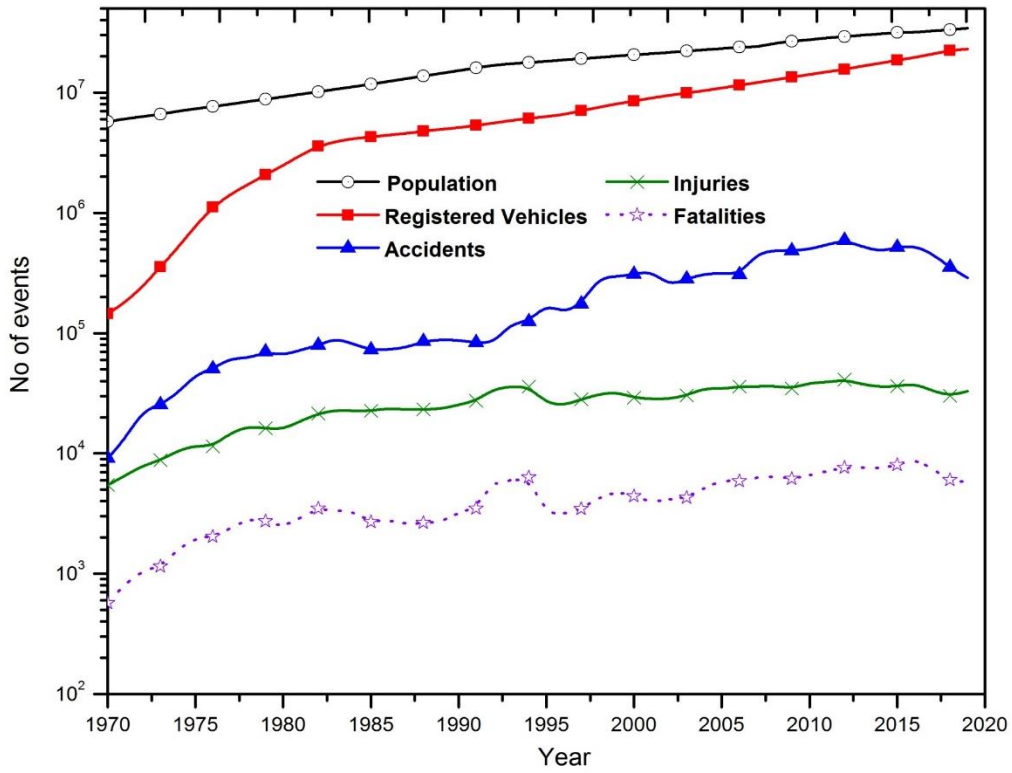

Fig. 4: Trend in population, registered vehicles, MVCs accidents, injuries and fatalities 1970-2018

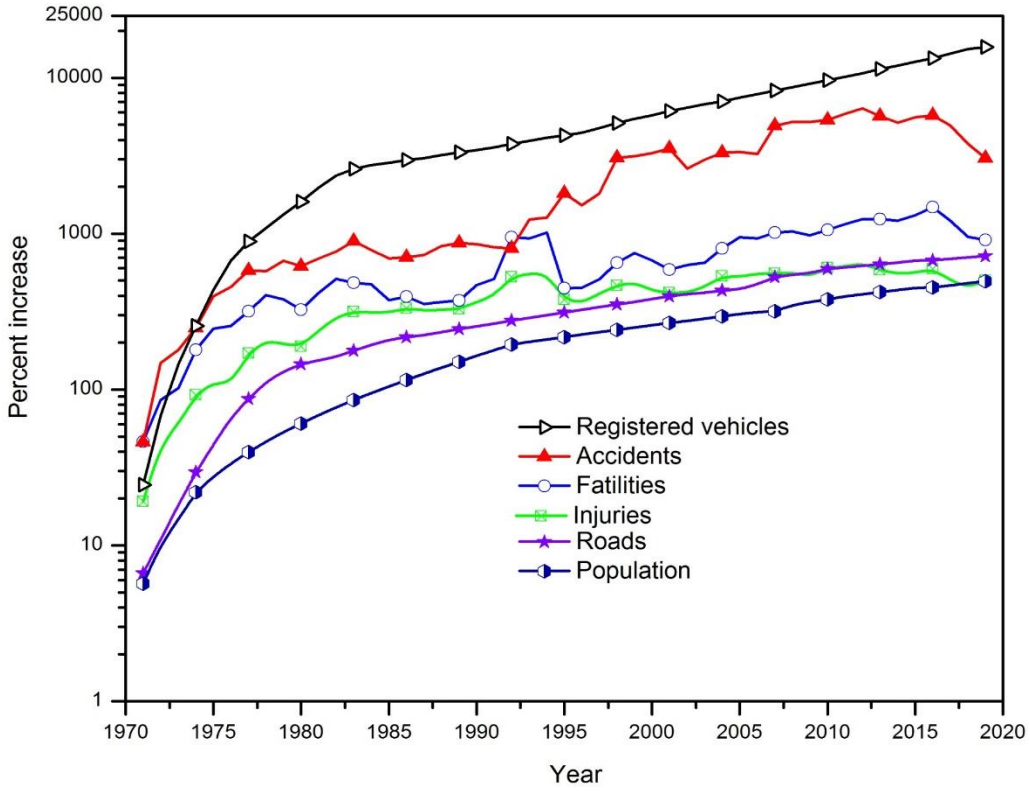

Fig. 5: Trends in MVCs and the resulting fatalities and injuries 1970-2018

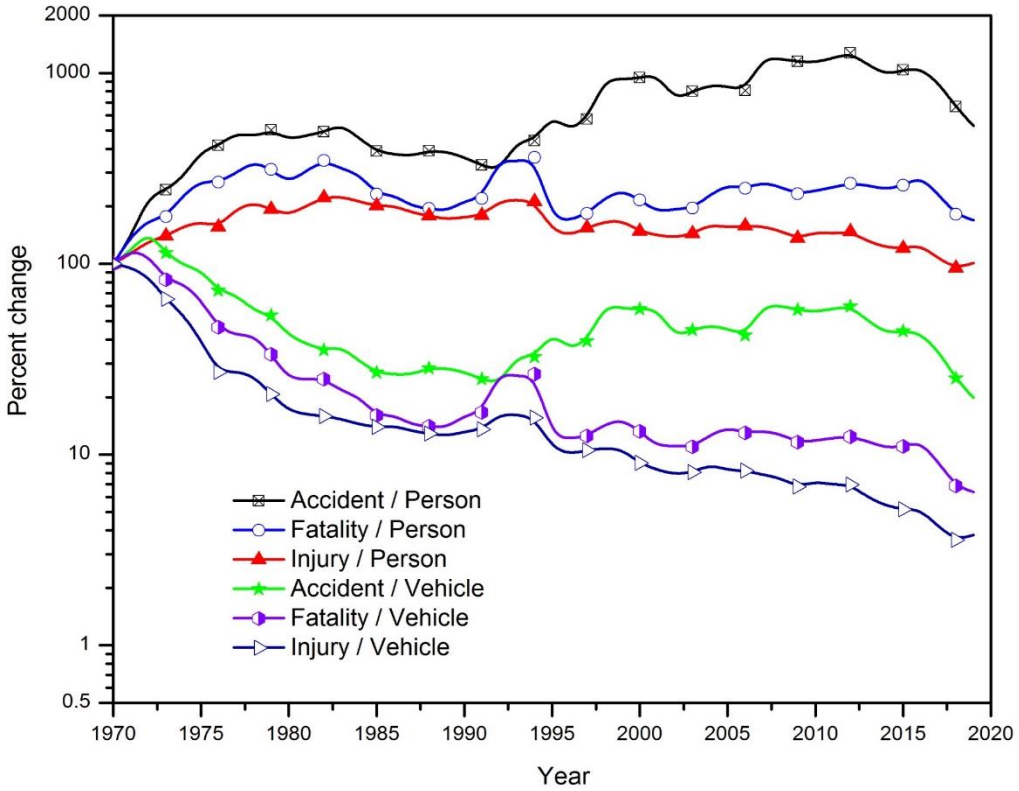

Fig. 6: Trends in injury, fatality and crash rates per person and per vehicle for the period 1970-2018

Mortality is an essential indicator of the scale of health problems, including traumatic injuries from road crashes for the countries. The current RTA mortality rate per capita (27) in the Kingdom is well above the global average rate (18.8) in 2013. A recent report indicated that Saudi Arabia is one of the ten highest countries with the highest number of road fatality rates in the world (WHO, 2015).

When the Saudi mortality rates from RTAs were compared with the equivalent rates in other countries, RTAs presented a grave public health problem in Saudi Arabia. For the rate based on population (F/P), the RTAs mortality in Saudi Arabia was exceeding other selected countries on the scale. Considering that in Saudi Arabia, the reported number of fatalities only includes victims who died on the scene, the fatality rate must be even higher than the rate shown in Fig. 6. The European Conference of Ministers of Transport (ECMT) provides a standardized 30 days adjustment factor of 1.30 to make the statistical data comparable. Using this factor, the fatality rate for Saudi Arabia would increase to 276 fatalities per 1 million populations (ETSC, 2017).

The results showed the ratio between road deaths, injuries requiring hospital treatment, and minor injuries to be 1:8:20. For the rate based on 10,000 motor vehicles (F/V), the Kingdom's rate was by far higher than the mean rate of Western Europe and North America. Whereas the UK and USA recorded 6 and 15 RTA fatalities per one billion vehicles per kilometers traveled (F/VK), Saudi Arabia recorded an uneven 110 fatalities per one billion vehicle-kilometers traveled. Albeit the ratio of vehicles to population is highest in the KSA (5.1 people per vehicle, compared to 2.2 people and 1.33 people per vehicle in the UK and USA respectively), the fatality rate per billion vehicles is nearly 18 times higher than that in the UK, and more than 7 times higher than in the USA.

RTAs have been identified as the main source of morbidity, mortality, and disability in Saudi Arabia at a rate that is on a level with heart diseases and cancer. It has become an epidemic second to infectious disease as a medical problem, and an epidemic as severe as the plague or smallpox was in prior generations (Almalki et al., 2011).

Official Statistics have shown that RTAs being the main cause of accidents mortality, followed by drowning and burns (MoH, 2018). During 2005-2012, road deaths have grown 42% quicker than the population in Saudi Arabia (WHO, 2015) (Fig. 7).

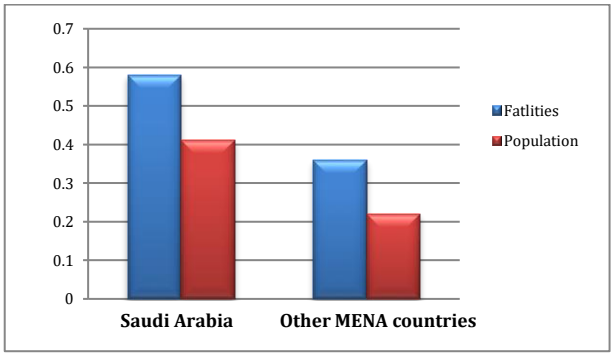

Fig. 7: Trend in Road Fatalities and Population in MENA (replotting after WHO (2015))

The hospitals recognize the burden placed on their services by road crashes with crash victims representing up to a third of Emergency Medical Services (EMS) casualties and also taking a considerable proportion of hospital beds. The total

number of beds in 274 Ministry of Health hospitals is 41,835 in 2015 (MoH, 2018). At any time, one-third of these beds are occupied by road traffic accident injury casualties. This is in addition to the EMS resources required at the scene of the accident and Pre-Hospital Care (PHC) of the victims for saving their lives (Alghnam et al., 2014).

This research work results showed that over 55% of road casualties in KSA are among young adults aged 15-44 years. This group constitutes 52% of the Saudi population. It also revealed that the mortality age-specific is 27.70 per 10^5 populations. Children are said to account for 17% of all road fatalities. One key finding is that RTAs very much target the young, which, in turn, threatens the future development of the country, which depends heavily on the contribution of the future generations (ADA, 2016).

4.1.1. Trends of MVC related injury and fatality rates

Detailed historical trend analyses of MVC data and their consequences were done based on statistics given in Table 1. Specifically, six commonly used rates were determined, which are the number of crashes per 100,000 populations, number of injuries per 1000 crashes, number of injuries per 100,000 populations, number of fatalities per 1000 crashes, number of fatalities per 100,000 population and number of fatalities per 10,000 motor vehicles. Those six rates over the 46-year period are plotted in Fig. 8.

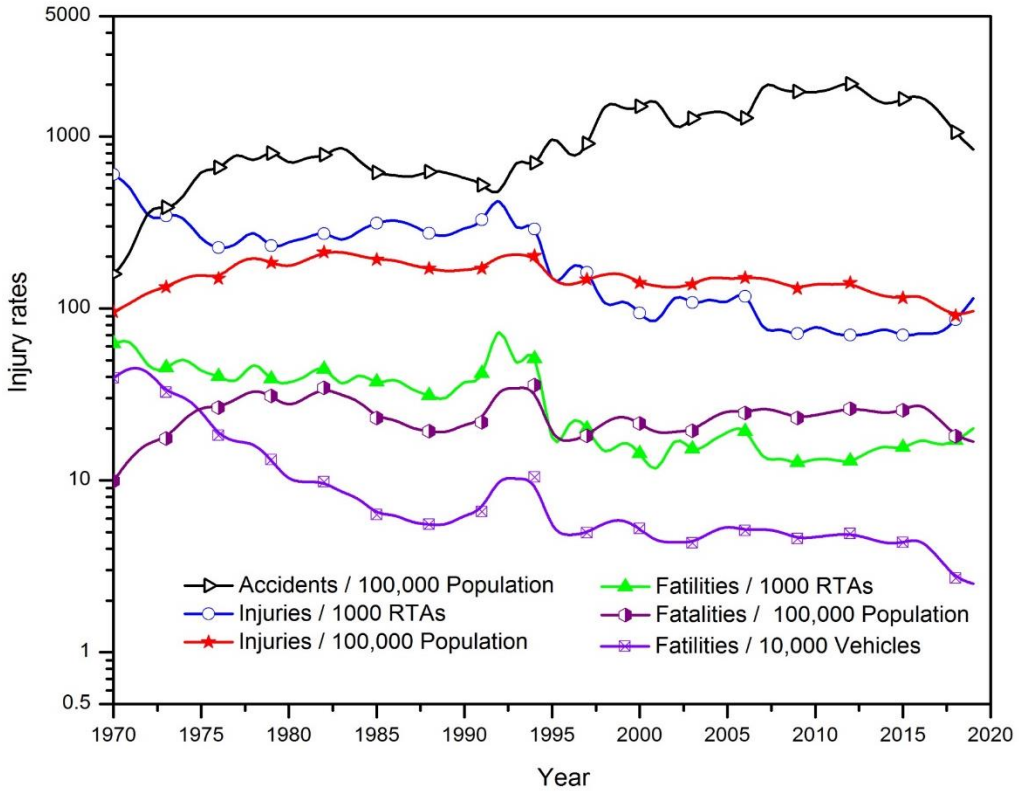

Fig. 8: Trends in MVCs, injury and fatality rates in Saudi Arabia 1970-2018

It can be clearly seen in Fig. 5 that crash rates per 100,000 populations have been increasing. Specifically, annual rates have significantly increased during the last 20 years compared to the previous 20 years. This increase can be attributed to the increase in domestic wealth, leading to an increase in vehicle ownership.

The trend in injury rate per 1000 RTAs has, on the other hand, decreased in the last 20 years. This decrease may be attributed to the introduction of safety features in vehicle design and improvements in highway engineering. Moreover, due to awareness programs, hefty fines, and teaching safety rules, drivers' behaviors are also improved.

On the other hand, the rate of injuries per 100,000 population increased up to 1994 and thereafter decreased during the period 1996–2006. This rate has then leveled off in the last ten years, but an increase was noted in 2016. The rate of fatalities per 100,000 increased prior to 1996 and then has more or less leveled off. Similarly, the rate of fatalities per 1000 RTAs decreased up to the year 1996. The average decrease slowed down in the following years up until 2012 and then showed an increasing trend. Finally, the fatalities rate per 10,000 vehicles showed a downward trend till 1988, then increased till 1994 and then dropped in the following two years and somehow stabilized after that.

4.1.2. Risk of RTAs in Saudi Arabia

The historical trend of the level of crash severity in Saudi Arabia between 1970 and 2018 was also

assessed by calculating the annual Odds Ratio (OD) of crashes. This trend, together with upper and lower limits and 95% confidence intervals are illustrated in Fig. 9 while taking the 1970 MVC figure as a base point.

The trend seen in Fig. 9 suggests that no improvement in the odds ratio of crash severity between 1970 and 2018 has been recorded in Saudi Arabia except during a short period between 1985 and 1990. It should also be noted that the odds ratio of crashes has been increasing significantly since 2010.

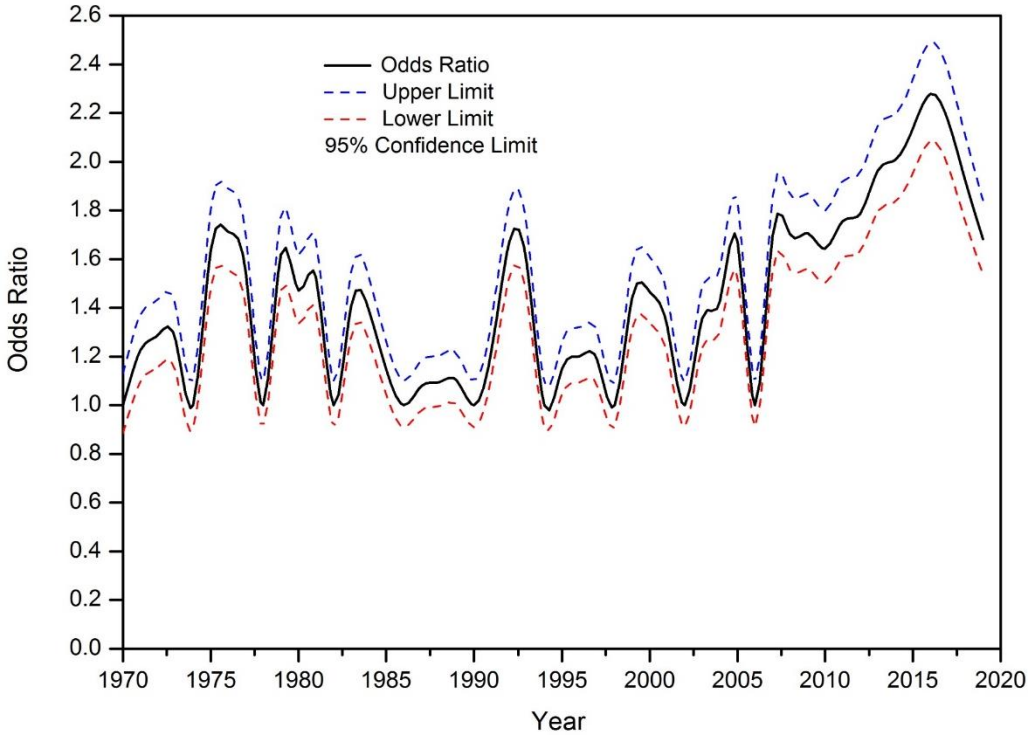

Fig. 9: Odds ratio of crash severity 1970-2018

4.2. Road crash characteristics

In an effort to improve road safety, it is imperative to study and assess road crash characteristics. In this sub-section, the results from the data obtained regarding the main road crash characteristics reported in official reports and the scientific literature are presented.

4.2.1. Types of motor vehicle collisions

The type of collisions that lead to deaths or injuries in Saudi Arabia was assessed. Fig. 10 shows the distribution of human losses by types of motor vehicle collisions. It can be seen that vehicle to vehicle impacts (69%) are the leading cause of severe injuries (AIS ≥4) followed by a fixed object (19%) and rollover collisions (6%).

4.2.2. Types of road injuries

The injuries due to MVCs by body regions for MVCs victims in Saudi Arabia were studied. The findings of this assessment are presented in Fig. 11. Results show that the thorax, head, and abdomen are the parts of the human body most exposed to severe injury due to motor vehicle crashes in Saudi Arabia. Moreover, the same study assessed the place of death, as shown in Fig. 12, and found that most of the victims died on crash scene or upon arrival to hospital (35%).

4.3. Consequences of MVC in Saudi Arabia

Accidents happen in a fraction of a second, but their consequences may last for days, months, years, or the rest of life. A large number of road users involved in traffic crashes recover from their injuries, but some of them never recover fully and suffer from some kind of permanent disability. In addition to the loss of life or reduced quality of life, road accidents carry many other consequences to the survivors, such as legal implications, economic burden, home, and vehicle adaptations, as well as psychological consequences.

4.3.1. Human loss due to road crashes

RTAs are increasingly being documented as growing public health, social, and economic problems in the Kingdom of Saudi Arabia. Relying solely on police reports might not reflect the full picture of human losses due to MVCs. In order to get a more comprehensive understanding of the extent of human losses in Saudi Arabia, it is incorporated health registration data on deaths due to traffic crashes. The findings showed that road crashes cause 3.86% of all mortalities recorded in Saudi

Arabia, while they cause less than 1.7% of all mortalities in many developed countries like Australia, England, and America (WHO, 2015).

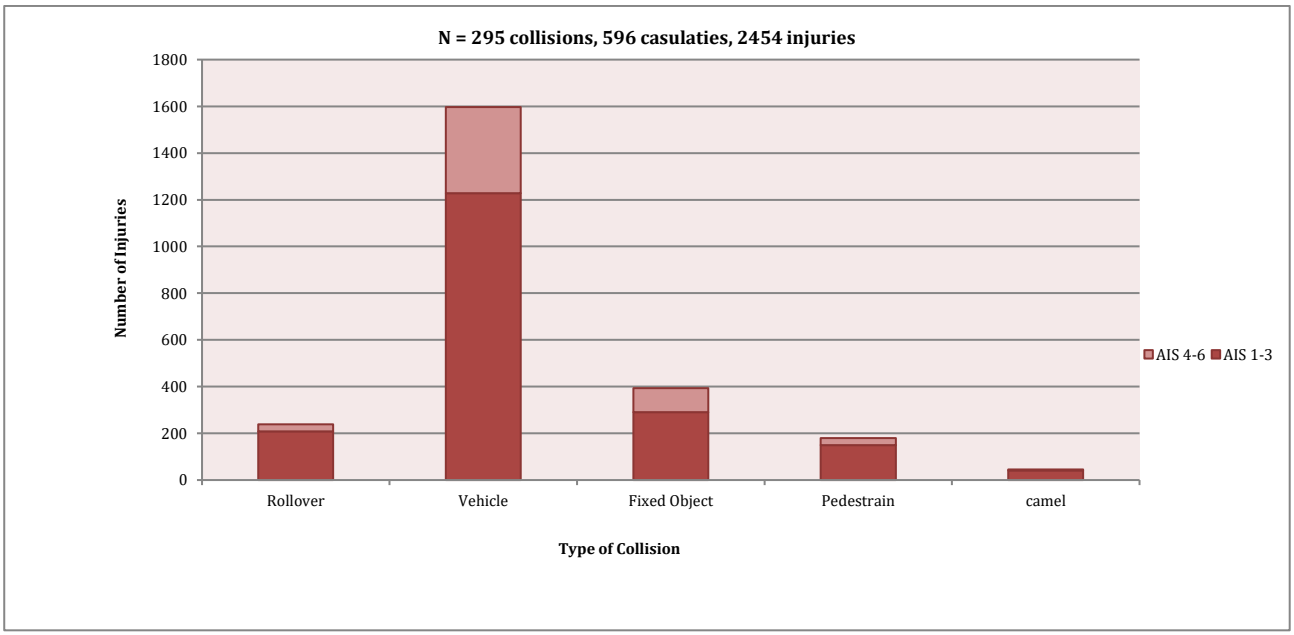

Fig. 10: Distribution of fatal and serious MVCs by type of impact

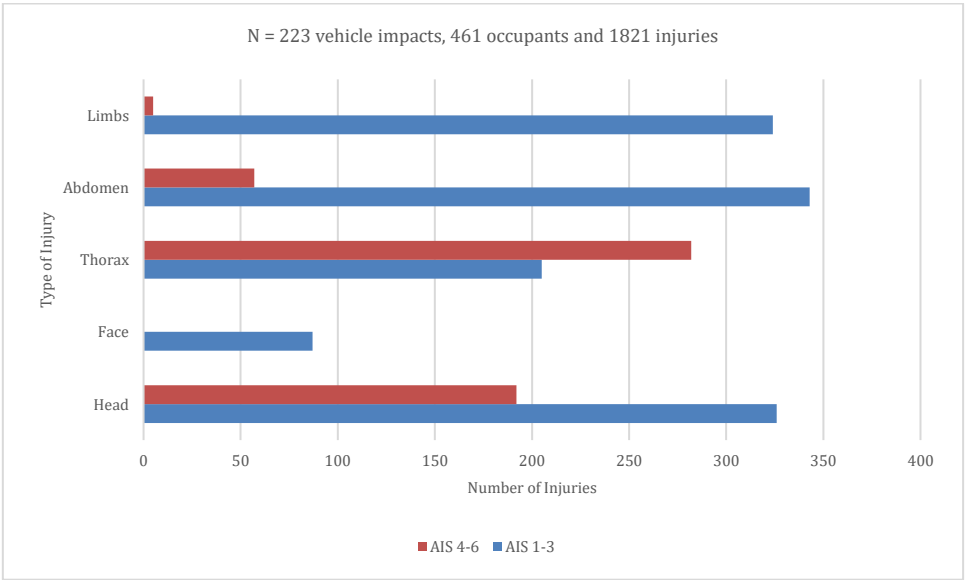

Fig. 11: Distribution of MVC injuries by body region

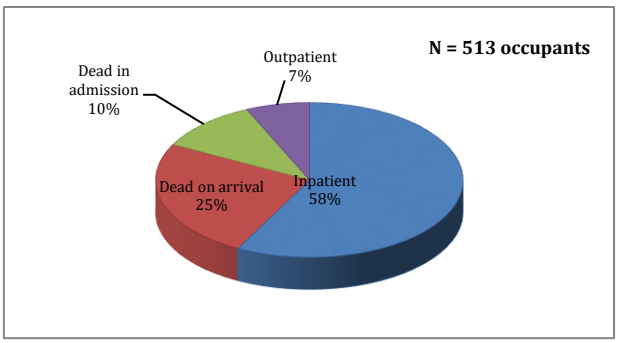

Fig. 12: Place of death of road crash victims in Saudi Arabia

Another way to look at this problem is to compare Saudi Arabia with other countries using different indicators of the magnitude of losses and for assessing performance and setting targets. Fig. 13, Fig. 14, and Fig. 15 show the number of MVC deaths per 100,000 populations, the number of deaths per 10,000 vehicles, and the number of deaths per one billion vehicle-km traveled, respectively, in 2018 for Saudi Arabia and some other selected countries. Data used in these figures

are based on data published by international traffic safety groups such as IRF (2016) and IRTAD (2018).

Fig. 13, Fig. 14, and Fig. 15 show clearly that Saudi Arabia is still experiencing very high human losses due to traffic crashes when compared to other countries as postulated previously. The figures also highlight the urgent need for improving traffic safety conditions in this country.

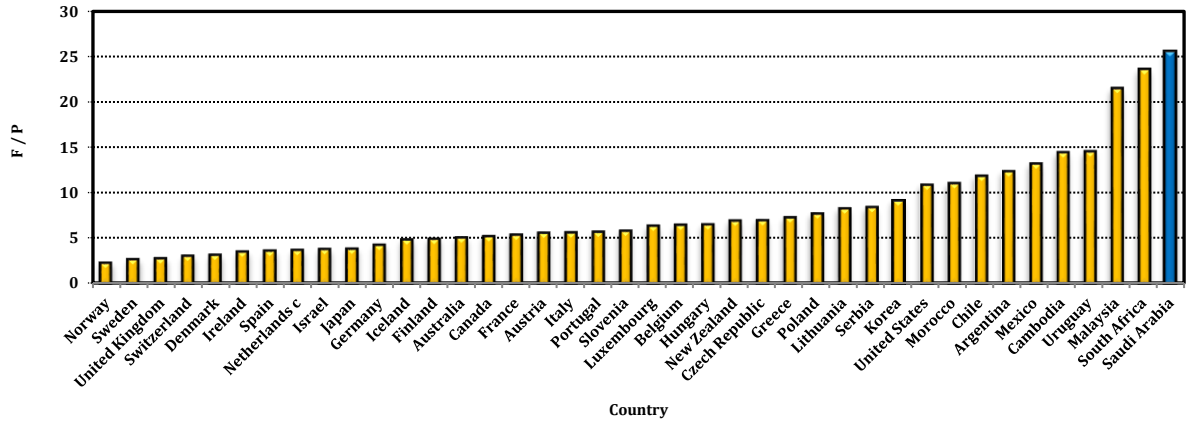

Fig. 13: Fatalities rate per capita for Saudi Arabia and other selected countries

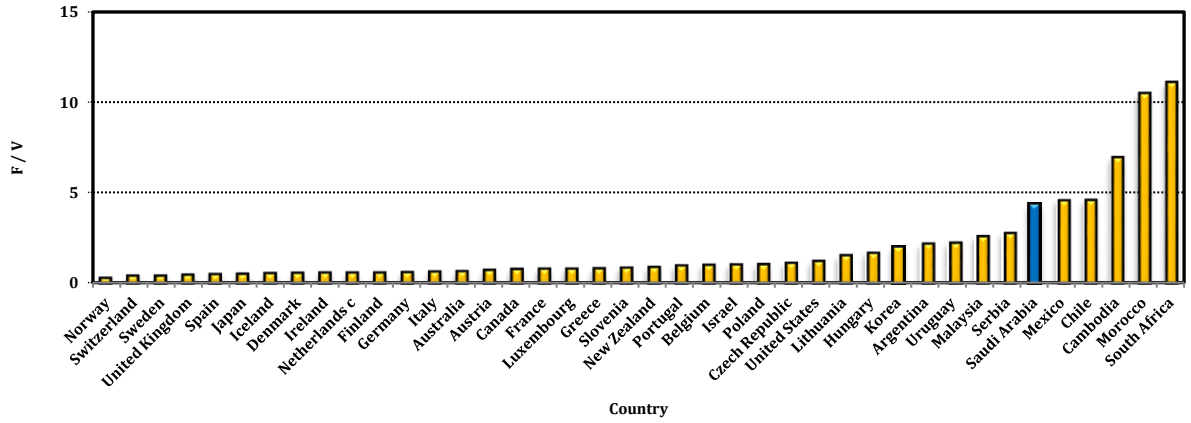

Fig. 14: Fatality rate per 10,000 vehicles in Saudi Arabia and other countries

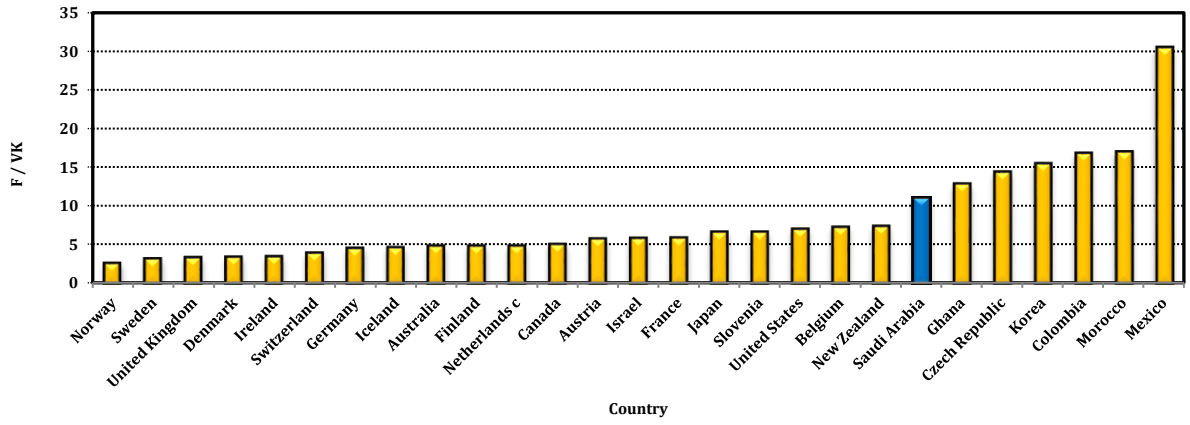

Fig. 15: Fatality rate per 1BVK in Saudi Arabia and other countries

4.3.2. Incidence and etiology of SCIs in Saudi Arabia

Injuries, intentional and unintentional, continue to be an important public health concern worldwide. Injuries to the spinal cord are common after a traumatic accident. Spine and spinal-related injuries have the lowermost functional results and the lowest rates of back to work after injury of all other major organ systems (Singh et al., 2014).

Spinal Cord Injury (SCI) is conceivably the most horrible of all survivable traumas. The destructive results of SCI in terms of loss of independence, psychological impact, and socioeconomic costs are

enormous. Disability, loss of productivity, extreme use of medical resources, and inexpressible human misery usually supplement these injuries. Like other economically developed countries, RTA also remains the most frequent cause of spinal trauma in Saudi Arabia and neighboring Gulf Countries (GCC). It has been shown that in GCC, motor crashes rates are higher than in western countries. Today auto accidents are the most common cause of fractures and dislocations of the spine. Data from the WHO project showed that almost a quarter of those injured severely in RTAs sufficient to necessitate admission to a health facility sustain a traumatic brain injury; 1.4% suffer long term SCI and 2.7 % experience fractures to the vertebral column. There are more than 3,000 deaths daily as a result of RTA, while 140,000 people are injured, and about 15,000 are disabled for life (WHO, 2015).

Although RTAs are the most common cause of 42-47% of all traumatic SCIs worldwide, this percentage in Saudi Arabia has exceeded all previous values (63%). This result exceeds all reported among recent studies in America, Europe, and Asia (Cripps et al., 2011), with the exception of the 72% reported in Qatar (Singh et al., 2014). The current incidence of SCI in the Kingdom has been identified to be higher than 85% of all countries with known SCI incidence in the world. The fact that a very high percentage of RTA cause SCI, there is a need for the execution of countermeasures in order to reduce the number of car accidents. Fig. 16 shows the global incidence rates of SCI per million populations because of RTAs.

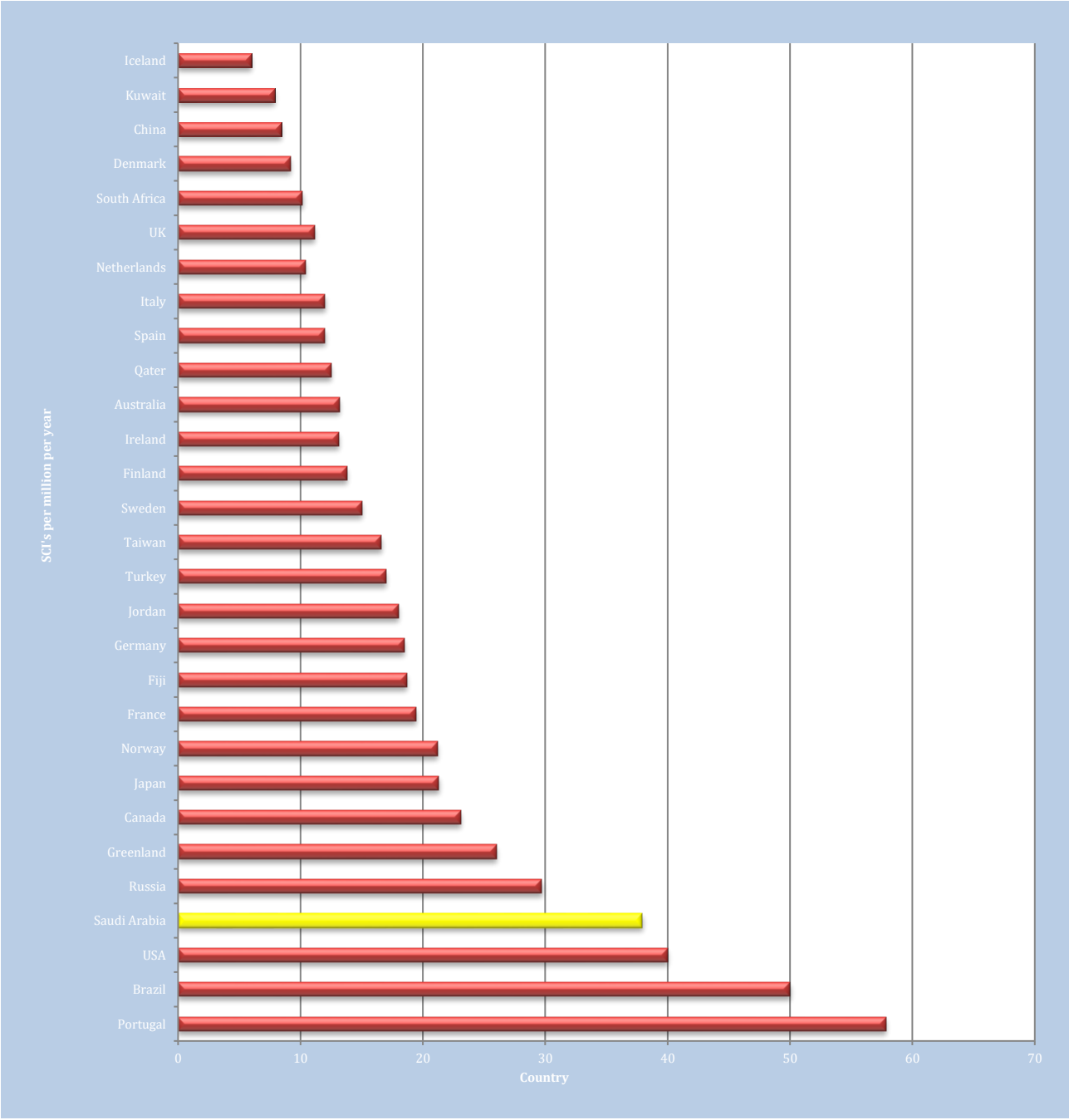

Fig. 16: Global incidence rates of SCI per million populations because of RTAs

Moreover, the neurological level of SCI (hemiplegia, paraplegia, or tetraplegia) due to RTA is also identified to be very high (67%). In terms of the number of road mortalities per million head of population, with 27 fatalities per 100,000 population, Saudi Arabia is internationally at the most upper-most limit of this indicator. Unfortunately, the majority of these fatalities (50-60%) occur in the prehospital phase. Seventy-one (71%) of the transport-related cases were vehicle occupants, and 23% were unprotected road users, predominantly pedestrians (96%). Of the vehicle crashes, 58% of SCI in Saudi Arabia was due to rollovers. In Saudi Arabia, the rollover of the car (56-59%) was identified as a major cause of SCI followed by camel collision (33%) and head-on collisions of vehicles (Al-Jadid, 2014). A study by Singh et al. (2014) on 110 MVC-related SCI cases showed that of these, 59% were injuries in the cervical cord segments, causing tetraplegia. The study stated that vehicle rollover was a chief contributor to SCI and that approximately 25% of injuries were linked with alcohol usage.

Instituting the appropriate factors related to SCI as they connect to the characteristics of a specified region and population is an essential step to frame strategies to mitigate the incidences of SCI. The information is required for control of SCI, and the monitoring of the health and welfare of the wider population shows the need for future surveillance in Saudi Arabia.

Local studies have shown that rash and negligent driving, not wearing seatbelts, and poor provision of first aid service on main roads are the main causes of long term spine injuries. Human factors were responsible for 70% of RTAs leading to SCIs in the country. Proper management of actions taken at the scene of the accident, appropriate transportation, and professional care in medical emergency centers can reduce the occurrence of paralysis and the severity of resulting complications. Emergency Medicine (EM) and Emergency Medical Services (EMS) within the country are still inadequate and inefficient with the KSA best called as being in the "developing" phase of EM. Currently, the Saudi Red Crescent Society (SRCS), the Ministry of Health (MoH), Civil Defense, and Police provide the majority of EMS services for the public.

The collected data from main trauma centers (2008-2018) showed that traumatic spinal injury accounted for 93% of all spinal injuries recorded in Saudi Arabia. Correspondingly, the proportion of spinal casualties has increased by 6 times during the period of 2008-2018 at 22% average annual growth. As a result, vertebral and spinal cord injuries accounted for 8.43% of hospital admissions for trauma centers during this period. The estimated overall average incidence of spinal cord injury was 57.92 per million, with an average prevalence of 812 new cases every year. Abbreviated injury scale (AIS) level 3 vertebral fractured occurred at the rate of 23.65 per 100,000, and admissions for less severe spinal injuries occurred at the rate of 47.22 per 100,000. In particular, cervical spine injuries were the most common spine injures, accounting for 39.73% with an incidence rate of 9.20 per 10^5, followed by lumbar (32.38%), thoracic (22.69%), and sacral (5.20%) injuries (MoH, 2018).

The survey showed that motor vehicle occupants accounted for 63% of the cases of SCI in Saudi Arabia. Fig. 17 shows the external causes of SCI casualties in Saudi Arabia.

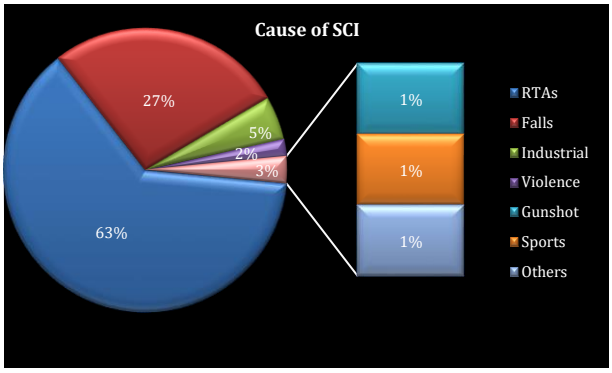

Fig. 17: Etiology of spinal cord injuries in Saudi Arabia

4.3.3. First aids and rehabilitation for SCI casualties in Saudi Arabia

Pre-hospital management seeks primarily to protect the casualty from further injury and to provide early resuscitation and transport to an appropriate acute care facility. Only 57% of all SCI casualties received first aid at the site by EMT, and the majority of casualties (49%) were reached by EMT within 11-20 minutes. The service coverage of EMS and trauma care in Saudi Arabia found to be relatively weak when compared with the corresponding service in other parts of the world. Restrictions that describe the poor result for people involved in road traffic crashes in Saudi Arabia have been recognized, and include lack of trained staff, and field paramedics; underserved medical facilities; unsuitable dedicated transportation; and disorganized or nonexistent emergency and trauma services (Alghnam et al., 2014).

The response time plays a vital role in curtailing the hostile effects: Fatalities and loss of property can be significantly lessening down by decreasing the response time for emergencies. It has been recognized that the response time of ambulance in the city of Riyadh is below acceptable standards when compared against developed nations such as the UK and the USA (Al Turki, 2014). The first ten minutes are known in trauma care as the thresholds in reducing rates of death or disability from life-threatening injuries. It has been shown that only 35% of road casualties in Saudi Arabia could have survived had they been evacuated at the scene within the platinum time (Mansuri et al., 2015). Also, it is noticed that in more than 19% of all the fatal crashes, it took more than 45 minutes to get crash victims to a medical treatment facility, not certainly a trauma center that could appropriately treat

potentially fatal injuries. Therefore, these figures tend to minimize the magnitude of the national problem of injured crash victims into operating rooms for definitive medical care within the "*Golden Hour*" (Padmanaban et al., 2009).

It was disappointing to discover that 81% of SCI casualties in Saudi Arabia have been transferred improperly to the hospital without any emergency or pre-hospital care because the transfer is done by the general public. The majority of crashes, which led to SCI, happened out of the city (intercity highways) (Al-Jadid, 2014). Those areas are poorly equipped by the SRCS services, and hence the response rate is expected to be longer than if the accident had occurred within the city boundaries (Alghnam et al., 2014).

Over the last 10 years (2008-2018), more than 44,000 spinal injuries were reported from vehicle crashes (SRCS, 2018). Among different injuries evacuated annually by SRCS, about 6% are spine-vehicle crashes related. Unfortunately, the fact remains that many, if not most, of these injuries, were preventable. Although overall fatalities are high in traumatic spinal cord injuries, i.e., approximately 50%, long term survival rates are quoted for persons surviving at least 24 hours to be 75-85% and are highest among persons below the age of 25 years. With the combined higher incidence of injury and survival amongst the young and a need for special services, creates an enormous economic burden on the casualties, their families and the society in Saudi Arabia (Almasri et al., 2015). Therefore, it is concluded that most of the fatal and disabling injuries in Saudi Arabia can be prevented by improving the EMS in the country.

Of those with a neurological deficit, 68% in this study were ASIA "A" and a large number of occupants (67%) sustained a cervical injury with tetraplegia. Compression-flexion (31%) and vertical compression (21%) were the most common mechanisms associated with spinal cord injuries in this study. In motor vehicle crashes, the cervical segments of the spine are most frequently damaged, resulting in tetraplegia. Ghaffar and Ahmed (2015) found that 61% of the cases of SCI from MVCs were tetraplegic. Haddad et al. (2015) found that 68% of cord lesions were in the cervical region, compared with 59% in the study by Singh et al. (2014).

In this study, two of the factors which may affect the function of the spine during the accident, viz, the first aid provider, and the response time in care being made available were considered and shown in Fig. 18.

Rehabilitation training programs are available to a few of the Saudi SCI casualties, most of the exercises given to them are carried out in a Physical Therapy department of general hospitals where therapists have minimal experience of spinal injury. Initial prevention is the best management for spinal injury. Information on the incidence and etiology of SCI is of importance in order to find risk groups, ameliorate prevention, and for preparation of care and rehabilitation. Research related to the epidemiology of SCI has mainly been descriptive, with a focus on primary prevention. This information is important for calculating the impact of SCI as measured by the incidence, prevalence, survival, and characteristics of those who receive such injuries.

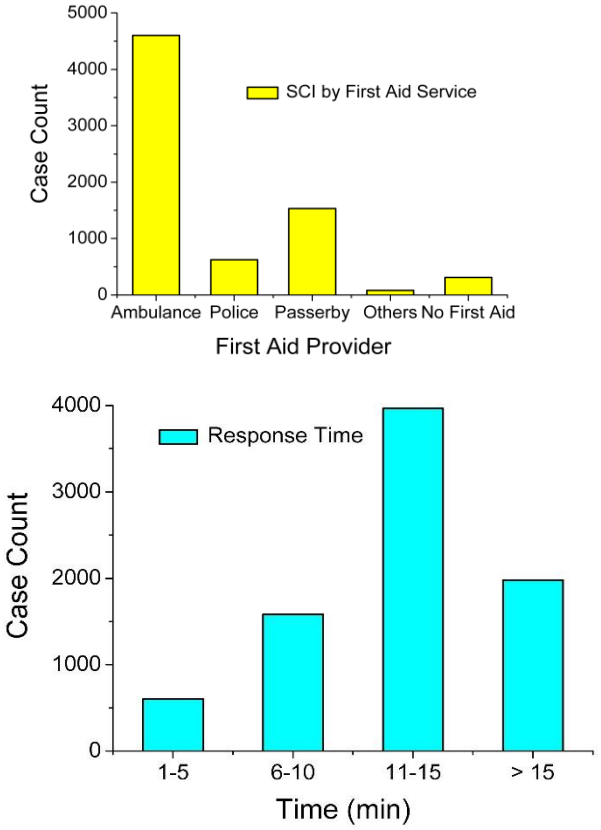

Fig. 18: Evaluation of EMS service and the response time

Methodologies for recording this info have varied extensively from retrospective attempts to record all cases of specific etiology over a given time period to prospective attempts to record all cases in a geographic region (Cripps et al., 2011). Nations with centralized health care and record-keeping have come closest to population-based estimated incidence and prevalence, and several state-based registries in the United States have attempted to do the same (Lee et al., 2014).

The male/female ratio of SCIs was high (6.40:1) comparing to the 3/1 to 6/1 male/female ratio in other studies (Singh et al., 2014). This is perhaps described by the fact that in Saudi Arabia, the majority of women are not allowed to drive due to the country policy and because most of them are housewives, therefore less exposed to the risk of SCI than in other countries. Furthermore, there is a large number of single immigrant males working in KSA, which also may help to explain this ratio. This was pointed out by Al-Jadid (2014) when he reported that the sex ratio reflects the socioeconomic and cultural status of the society. However, it was noticed that the male/female ratio has decreased from 9/1 into 6/1 in the last ten years. The reason for that, it might because many Saudi women have

become involved in more outside activities and jobs in recent years.

There was a noteworthy growth in SCIs caused due to RTAs for males aged 55-64 years, while there was an acute upsurge for females aged 55-64 years. The highest age-specific rate happened in the age group of 15–24 years. Male rates of continuing SCI from traumatic causes were higher than female rates at all ages. As in most of the studies (Robert and Zamzami, 2013), the peak incidence of SCI is within the age group of 21-30 years, comprising 35.8%. In Saudi Arabia, as is the case in most developing countries, the population is very young. Nearly two-thirds of the population is under the age of thirty, and this means that the figure of the peak incidence of SCI goes with the demographic structure of the society.

Out of all SCI casualties, 88 were provided first aid at the site of the accident, out of which 57% received first aid by the Emergency Medical Team (EMT) of SRCS, 19% by a passerby, and 8% by police or relatives and friends. Surprisingly, 4% of casualties did not receive first aid at the site. There were 65% of casualties transported to the hospital by an ambulance, 25% by normal transport, and 8% were airlifted.

Only 27% of the SCI casualties received first aid within the first ten minutes, while 49% received first aid within 11-20 minutes, and 24% received first aid after 15 minutes. There were 35%, and 44% of casualties reached hospital within 15-30 minutes and 31-45 minutes, respectively, while 6% reached the hospital after 1 hr.

The fact that a very high percentage of RTA causes serious to disability injury urge for the implementation of measures in order to decrease the number of car accidents in these countries. The high incidence rate of spinal cord injury experienced in Saudi Arabia might be attributed to the following factors:

1. Lack of appropriate pre-hospital trauma care leading to disability and low survivability of victims in road accidents (Mansuri et al., 2015);
2. Aggressive behavior and driving offenses of traffic regulations especially by young drivers, (DeNicola et al., 2016; Alghnam et al., 2017); and
3. Non-compliance of wearing seatbelts and other restraints (Klair and Arfan, 2014).

4.3.4. Economic losses due to road crashes

With only 2% of the world's motor vehicles, 4% of the world's population lives in the Middle East and North Africa (MENA) region, which experiences 6% of the global road fatalities (WHO, 2015). Amongst young men aged 15–29 years, the Middle East possesses the world's highest traffic fatality rate at 34.2 deaths per 100,000. The deaths are projected to cost US$ 7.4 billion yearly. Traffic fatalities are expected to rise by 68% by the year 2020. Injuries caused 16% of all deaths. Worldwide and local records reported that there are 40 million people with disabilities who have inadequate access to rehabilitation and almost nonexistent social reintegration (WHO, 2015).

A more recent study using the 'Gross Output' approach demonstrated that road accidents might be costing the Kingdom of Saudi Arabia US$ 6.73 billion annually (ADA, 2016). Costs have been calculated using only resource costs with amounts added for 'Pain, Grief and Suffering' followed by adding 'Human' costs assessed by what is known as 'Willingness to Pay' (WTP) approach. Fig. 19 shows a summary of resource costs for all types of MVCs, including Property Damage Only (PDO) accidents in Saudi Arabia based on data published in ADA (2016).

5. Conclusions and recommendations

The work starts with an overview of the problem of RTAs in Saudi Arabia. The primary purpose of this investigation is to gain some insights into the causes and factors related to human, vehicle, and road, which directly or indirectly lead to the occurrence of fatal and disabling injuries. Effective preventive strategies of the fatal injuries exist and need to be applied through multi-disciplinary approaches in which the trauma care and road safety issues can play a distinctive and more active role. It is with this view. This research work was being conducted to in-depth study for the Road Traffic Accidents in the Kingdom with a broader and comprehensive perspective.

The research work outlines the epidemiology of RTAs in Saudi Arabia. Such epidemiological information has not been available before. Moreover, there was no national injury registry system, which makes it difficult to know the exact number of road crashes casualties. The data can be used to plan future unit development, recognize areas where precautionary campaigns can be targeted, and highlight the economic cost of acute spinal injury in Saudi Arabia.

Results showed that this country had advanced its road network at an enviable rate over the last half-century. However, despite the tremendous effort to minimize the number and severity of road crashes, they still grew over the same period. The historical review of RTAs in Saudi Arabia showed that more than one million people died or were seriously injured in road traffic accidents during 1970-2018, a figure equivalent to 4.48% of the total Saudi population in 2018. The analysis of the severity of traffic accidents in KSA suggested that no improvement in the odds ratio of crash severity between 1970 and 2018 except during a short period between 1985 and 1990. The fatality rate per person increased by 287% while the fatality rate per vehicle decreased to 12% during the period 1970-2018. Many such types of data were collected and analyzed comprehensively in this study, and it was revealed that Saudi Arabia has higher mortality and injury rates than other developed countries. The current RTA mortality rate per capita (27) in Saudi Arabia is well above the global average rate (18.8) in

2013. The study indicated that KSA is one of the ten highest countries with the highest number of road fatality rates in the world. Among the main causes contributed to RTAs in Saudi Arabia, violating speed limit ranks first followed by running the red light. In 2018, nearly 28% of crashes leading to injuries or deaths were attributed to speeding in excess of posted speed limits.

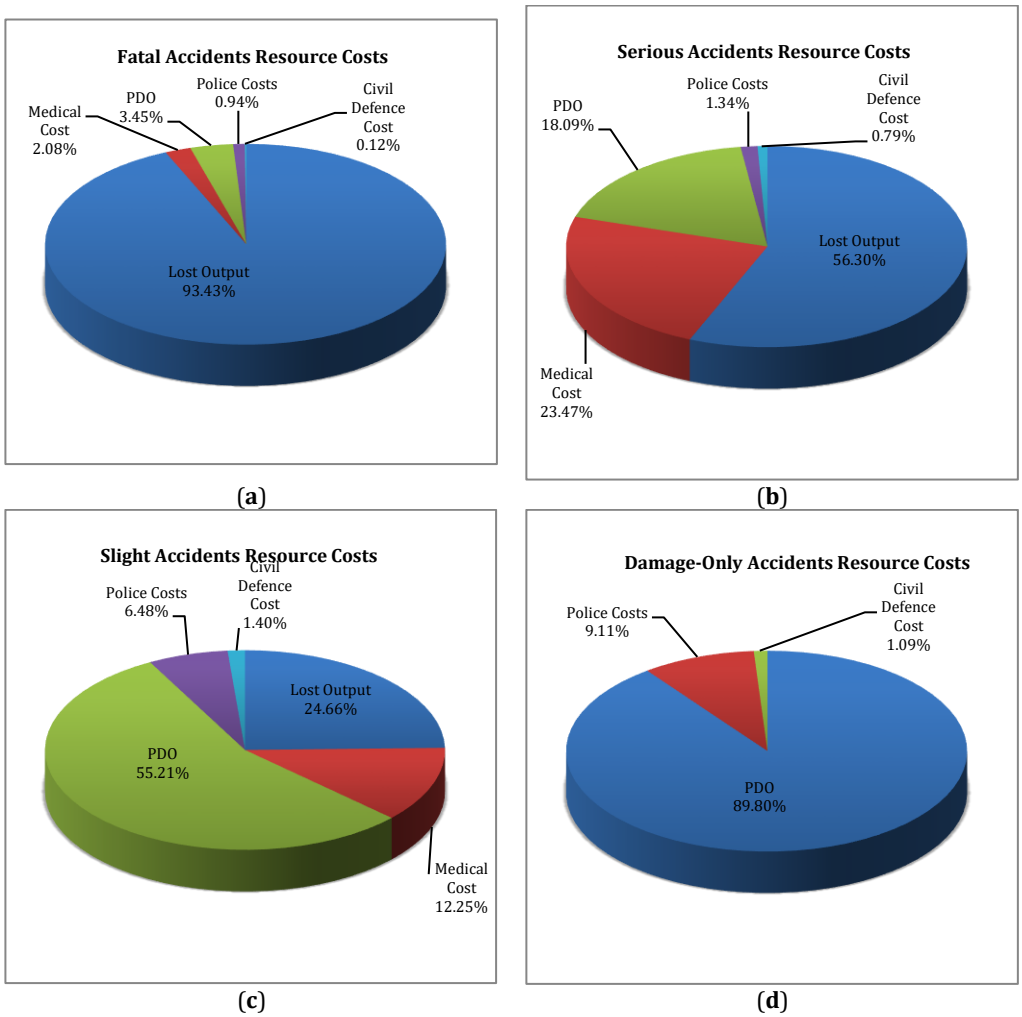

Fig. 19: Distribution of costs for all MVCs in Saudi Arabia (ADA, 2016)

Among the causes, it was revealed that reckless driving by young drivers is the main cause of RTAs in Saudi Arabia. They do not generally adhere to road safety regulations, especially tending to drive at speeds above the speed limit. Pedestrian also do not follow the regulations of the road crossing, and thus meet with accidents. More than one-fourth of the severe crashes in Saudi Arabia are pedestrian-related. Results also revealed that 42% of all pedestrian victims were aged 15 years or younger. A large proportion of drivers and passengers did not wear their seat belts. Moreover, children of less than six years of age were found to be more exposed to risk during vehicle collisions than other casualties in Saudi Arabia because only a small portion of the population uses the child car seat. One of the studies emphasizes the fact that an important factor for the high road traffic crash rates is the high influx of expatriate workers, with some of them coming from countries where most road users do not adhere to traffic regulations and accept high risk when on the road.

One key finding is that road accident target young people, which in turn threatens the future development of the country, which depends heavily on the contribution of future generations. Due to RTAs, Saudi Arabia has both human as well as economic losses. Most of the injuries happen to the upper parts of the body of injured people and hence make him/her disabled, which can be an important workforce asset to the nation. The study demonstrated that road accidents might be costing the Kingdom of Saudi Arabia US$ 6.73 billion annually. This represents 2.2% to 4.7% of Gross Domestic Product (GDP) is lost every year due to MVCs.

One of the most prominent results of this study was that almost one-third (35%) of total RTAs victims were either died on-site or just when they reached the hospital. Of those who survived long enough to be treated, 84.20% died in the intensive care unit, which worked as an extension of the emergency room, to which severely injured casualties were preliminary triaged. Only 12% died in hospital departments. Studies globally had suggested that death can possibly be avertible in a large amount of those who perished before they arrived at the hospital.

Therefore, RTA is a major problem faced by Saudi Arabia. However, to tackle it. Still, appropriate measures are not available, especially emergency medical services. Due to a lack of quick response in emergency services, fatal injuries occurs, such as SCIs, paralysis, etc. RTA is the main cause of SCI in Saudi Arabia (63%), which exceeds all reported among recent studies in America, Europe, and Asia. The results showed that the proportion of spinal casualties has increased by 6 times during the period of 2008-2018 at 22% average annual growth. Of the 28 studies found on the prevalence and the incidence of SCI in this research, the present incidence of SCI in Saudi Arabia is the highest rate ever reported in 85% of developed and developing countries.

This urge a need for the execution of countermeasures in order to reduce the number of car accidents. More rehabilitation training programs and specialized centers are required for patients with SCI and other fatal injuries. Moreover, there is an urgent need for behavioral changes among road users in Saudi Arabia in order to minimize the risk of MVCs and improve the state of traffic safety. Such behavioral changes can only occur with enhancing awareness of road users, introducing more stringent traffic regulations and tougher penalties, and bringing engineering solutions to the problems mentioned throughout this study. It is also clear from the findings of this study that most people in Saudi Arabia rely on private motor vehicles for their transportation needs. It is absolutely necessary that authorities need to enhance the public transport system as a way to give road users alternative ways for transportation like trains and buses, such as the current east-west and north-south railway projects, which is the right step undertaken by the government.

It is evident that only a few studies have combined clinical patient observations with professional crash reconstruction-derived data. Moreover, none of them tried, on a national level, to identify the relative frequencies of injury and quantify differences due to impact type, crash severity, seating position, restraint use, and demographic data of human casualties involved. More research work is required in these areas. In the current work, the observed increasing trend in crashes, fatalities, and injuries in recent years may be attributed to the increase in traffic volume and vehicle population and the saturation of the effects of previously implemented safety measures. Therefore, there is currently an urgent need to develop and introduce new and more up-to-date safety measures that are appropriate for Saudi Arabia if the increasing trend in crash rates and human losses are to be arrested or reversed.

Finally, it is clear that there is a lack of a centralized road crash database in the country to aid the development of road safety policies, regulations, technological changes and to set realistic targets to improve traffic safety. Such a database is urgently needed and should include detailed information on crash causes, victims, drivers, medical consequences, weather conditions, time, location, and others. Based on the data analysis and records, it is suggested that evaluation of the road safety management within the context of the country's health care and the effectiveness and safety of interventions in post-trauma care throughout Saudi Arabia is highly required.

At the moment, there are no consistent medical control or treatment protocols, communications systems, systems management, triage protocols, training or education, or quality assurance policies.

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Compliance with ethical standards

Conflict of interest

The authors declare that they have no conflict of interest.

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