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Original Article

## Do crashes happen more frequently at sunset in Ramadan than the rest of the year?



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### المخلص

**أهداف البحث:** تختلف وبائيات الإصابات المرورية على الطرق في أوقات حدوثها بسبب الاختلافات في ديناميكيات المرور أو السلوكيات. تهدف هذه الورقة إلى تقييم ما إذا هنالك اختلافات في إصابات حوادث المرور عند غروب الشمس بين رمضان والأشهر الأخرى في المملكة العربية السعودية.

**طرق البحث:** دراسة مقطعية على الصعيد الوطني لجميع إصابات الحوادث المسجلة في قاعدة بيانات هيئة الهلال الأحمر السعودي. كانت الحالات هي أولئك الذين طلبوا رعاية الطوارئ بعد أي إصابة مرورية في عام 2021. تمت مقارنة الاختلافات في نسبة الإصابات بين شهر رمضان والأشهر الأخرى باستخدام اختبارات مربع كاي. تم إنشاء نموذج انحدار لوجستي لتقييم الارتباط بين شهر رمضان واحتمال وقوع حوادث وقت غروب الشمس.

**النتائج:** بلغ العدد الإجمالي للإصابات 112.188 إصابة منها 9.922 (8.8%) حدثت في شهر رمضان. ولوحظ ارتفاع نسبة الإصابات خلال شهر رمضان مقارنة بالأشهر الأخرى بين الذكور (82.2% مقابل 79.6%) وغير السعوديين (42.7% مقابل 38.9%). وقد كان التأثير بين رمضان والمنطقة الجغرافية ذا دلالة إحصائية في نموذج الانحدار. كما كان احتمال إصابات الحوادث في رمضان أكثر بمرتين تقريبا عند غروب الشمس مقارنة بالأشهر الأخرى في الحدود

الشمالية (نسبة الأرجحية = 2.14) بينما تم العثور على الارتباط المعاكس في منطقة الباحة (نسبة الأرجحية = 0.67).

**الاستنتاجات:** عيب إصابات الحوادث أعلى في رمضان منه في الأشهر الأخرى وهذا يختلف حسب المنطقة. هناك ما يبهر مزيدا من الاستثمار في استراتيجيات الوقاية، مثل رفع مستوى الضبط المروري وبرامج التوعية، خاصة في المناطق ذات العبء المرتفع لتحسين السلامة المرورية وصحة السكان.

**الكلمات المفتاحية:** إصابات حوادث الطرق؛ رمضان؛ المملكة العربية السعودية؛ السلامة المرورية؛ الوقاية من الإصابات

### Abstract

**Objectives:** Because the epidemiology of road traffic injuries (RTIs) can differ in time due to differences in traffic dynamics or behaviors, this paper aims to examine whether RTIs are more likely to occur at sunset in Ramadan than in other months in KSA.

**Methods:** A nationwide cross-sectional study of all RTIs recorded in the Saudi Red Crescent Authority database. Cases were those who sought emergency care following any RTI in 2021. Differences in counts of RTIs between Ramadan and other months were compared using Chi-2 tests. A logistic regression model was constructed to evaluate the association between Ramadan and the likelihood of sunset RTIs.

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**Results:** The total number of RTIs was 112,188, of which 9922 (8.8%) occurred in Ramadan. Higher percentages of RTIs during Ramadan as compared to other months were observed among males (82.2% vs. 79.6%;  $P < .01$ ) and non-Saudis (42.7% vs. 38.9%;  $P < .01$ ). Interaction effects between Ramadan and region were significant in the regression model ( $P < .01$ ). RTIs in Ramadan were almost two times more likely to occur at sunset than in other months in the Northern Borders (OR = 2.14; 95% CI:1.44–3.17), while a negative association was found in Bahah region (OR = 0.67; 95% CI: 0.44–0.99).

**Conclusion:** RTI burden is higher in Ramadan than in other months, and that varies by region. Further investment in prevention strategies, such as increased enforcement and awareness programs, is warranted in regions with a higher RTIs burden to improve traffic safety and population health.

**Keywords:** Injury prevention; KSA; Ramadan; Road traffic injuries; Traffic safety

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## Introduction

Road traffic injuries (RTIs) are a global health issue and pose a major economic burden that affects development and prosperity.<sup>1</sup> In KSA (SA), RTIs represent a serious threat to population health because they are the second leading cause of death and strain its healthcare system.<sup>2</sup> According to the Ministry of Health (MOH), despite improvements in traffic safety in recent years, the number of deaths due to RTIs remains high.<sup>3</sup> In 2020, 4618 lives were lost, mostly among young victims.<sup>4</sup> Individuals 19–30 years of age are the worst affected by the burden of RTIs, which inevitably affect population health.<sup>5</sup>

SA is a Muslim country, and one of its most valued seasons is the holy month of Ramadan. Fasting has several health benefits, including weight reduction, cancer prevention, and improved cardiovascular health and hormonal regulation.<sup>6</sup> On the other hand, life changes during fasting may affect daily functioning. For example, fasting-induced malnutrition can reduce a driver's attention span, reflexes, and physical and cognitive capacities (i.e., reduced driving capacity), increasing the risk of collisions.<sup>7</sup> In addition, sleep deprivation is also another risk factor for crashes during Ramadan.<sup>8</sup> Importantly, investigations on the impact of fasting on health outcomes or RTIs remain scarce. While most studies have identified behaviors that increase RTIs, such as speeding and using cell phones, little has been done to investigate time factors, such as holidays or special occasions.<sup>9,10</sup> In particular, only some literature had identified factors that increase during Ramadan and may influence RTIs, such as speeding and non-compliance with seatbelt laws.<sup>11</sup>

“Maghrib,” which is sunset in Arabic, is an essential aspect of Ramadan because it signifies breaking the fast. During Ramadan, individuals frequently hit the streets before sunset to get their groceries or to visit friends and families. Some may speed or violate other traffic laws to ensure they get back home on time to break the fast. Long waiting times at stores before sunset may increase travel time or stress levels, leading to road rage among drivers. Consequently, individuals may get into brawls leading to injuries.<sup>12</sup>

Enhancing road traffic safety is one of four objectives under Saudi's Health Sector Transformation Programs of Vision 2030.<sup>13</sup> To address the burden of RTIs, previous local and international literature has focused on various behavioral factors to reduce the risk of RTIs.<sup>14–17</sup> Looking more broadly at other factors may complement public health efforts to raise traffic safety.

Evaluating RTIs and their association with Ramadan may support efforts toward promoting public health and safety. Therefore, this study aims to examine the association between the season (i.e., Ramadan) and RTIs at sunset and whether they differ by region in the Kingdom.

## Materials and Methods

This cross-sectional study includes all RTIs recorded in the Saudi Red Crescent Authority (SRCA) database in 2021. Any injury is registered to the database if a call for help was documented to the emergency number 997 requiring prehospital services. In addition, the database includes RTIs reported via smartphone applications, such as “Tawakalna” and “Asafny”. Tawakalna is an application sponsored by both the Ministry of Interior and the Ministry of Health to guide efforts to compact COVID-19, such as infection status, testing, and vaccination. In addition, this application includes a feature to request emergency services from the SRCA. Asafny is an application sponsored by the SRCA and has many features, including calling for emergency care or transport. In the SRCA database, the case is reported whether or not the patient was eventually transported to a healthcare facility.<sup>18</sup> The paramedic records all information related to the injury via electronic tablets. The SRCA stores all patients' data in a secured server, displaying dashboards to monitor trends and guide healthcare delivery.

The SRCA captures three mechanisms directly relevant to RTIs: motor vehicle crash, rollover, or pedestrian injury. In addition, the database includes demographic data, incidence location, and classification of severity based on information received from the dispatcher.

The database for emergency cases includes several variables such as age, gender, nationality, cause of the injury, location of the incident, region, time (incident, call, transport, reaching the hospital), or whether it occurred inside or outside the city. Classification of the case as urban or rural depends on whether the incident occurred inside (urban) or outside primary city limits (rural). The city limits were those beyond the urbanized area and the start of highways connecting a city to another city or region.

*Exposure variable*

Ramadan was the exposure variable and was defined based on the Islamic calendar year. Specifically, we classified an RTI as one taking place during Ramadan or at other times of the year.

*Outcome variable*

The primary study outcome is the frequency of RTIs at sunset. An injury was classified as one occurring at sunset if it occurred between 5:30 PM and 7:00 PM.

*Statistical analysis*

STATA 15 was used for all statistical analyses. The data was obtained from the data warehouse of the SRCA in Excel format, and data management was performed prior to the analysis. Descriptive statistics were performed to compare injuries during Ramadan to those in the rest of the year. Mortality rates by month were also calculated and depicted. Statistical significance was set at a P-value less than 0.05.

We constructed a logistic regression model to evaluate whether RTIs during Ramadan were associated with the likelihood of occurring at sunset. We hypothesized that the

association between Ramadan and RTIs during sunset is modified by region. Therefore, we tested for interaction effects between Ramadan and region, which was significant. Therefore, the interaction term was included in the final model. Results are presented as Odds Ratios (ORs) along with associated 95% confidence intervals. The ORs for the interaction effects were obtained using the *Lincom* command in STATA 15. The study was reviewed and approved by the Institutional Review Board (IRB) of the SRCA (No 21-E1-Dated: 12/09/2021).

**Results**

In 2021, over 112,188 RTIs sought medical care by the SRCA, with a monthly average of 9349 per month. In Ramadan alone, SRCA reported 9922 RTIs, slightly higher than the monthly average. There were no significant differences in RTIs among several age groups ( $P = .6$ ) and regions ( $P = .2$ ) between Ramadan and other months. Higher percentages of RTIs during Ramadan as compared to other months were observed among males (82.2% vs. 79.6%;  $P < .01$ ) and non-Saudis (42.7% vs. 38.9%;  $P < .01$ ). Furthermore, the RTIs-related mortality rate was higher in Ramadan than in other months (1.9% vs. 1.6%;  $P = .04$ ) (Table 1). There was no major variation in mortality rate across the year (Figure 1).

**Table 1: Descriptive characteristics of patients injured in Ramadan relative to other months in 2021.**

| Variables                                       | Injured in other months<br>N = 102,266 (%) | Injured in Ramadan<br>N = 9922 (%) | Total<br>N = 112,188 (%) | P-value |
|---|--|------------------------------------|--------------------------|---------|
| <b>Age</b>                                      |  |                                    |                          |         |
| 0–18  | 13,861 (14.03)                             | 1304 (13.57)                       | 15,165 (13.99)           | 0.60    |
| 19–40   | 64,630 (65.43)                             | 6315 (65.74)                       | 70,945 (65.46)           |         |
| 41–65   | 13,429 (13.60)                             | 1328 (13.82)                       | 14,757 (13.62)           |         |
| >65   | 6857 (6.94)                                | 659 (6.86)                         | 7516 (6.93)              |         |
| <b>Gender</b>                                   |  |                                    |                          |         |
| Unknown   | 5290 (5.18)                                | 508 (5.12)                         | 5798 (5.17)              | <0.01   |
| Female  | 15,610 (15.27)                             | 1255 (12.65)                       | 16,865 (15.04)           |         |
| Male  | 81,304 (79.55)                             | 8156 (82.23)                       | 89,460 (79.79)           |         |
| <b>Nationality</b>                              |  |                                    |                          |         |
| Non-Saudi                                       | 39,762 (38.88)                             | 4238 (42.71)                       | 44,000 (39.22)           | <0.01   |
| Saudi   | 62,504 (61.12)                             | 5684 (57.29)                       | 68,188 (60.78)           |         |
| <b>Region</b>                                   |  |                                    |                          |         |
| Riyadh  | 28,909 (28.27)                             | 2682 (27.03)                       | 31,591 (28.16)           | 0.26    |
| Northern Borders                                | 1127 (1.10)                                | 123 (1.24)                         | 1250 (1.11)              |         |
| Asir  | 9083 (8.88)                                | 852 (8.59)                         | 9935 (8.86)              |         |
| Bahah   | 1818 (1.78)                                | 190 (1.91)                         | 2008 (1.79)              |         |
| Eastern Region                                  | 11,097 (10.85)                             | 1087 (10.96)                       | 12,184 (10.86)           |         |
| Hail  | 2765 (2.70)                                | 273 (2.75)                         | 3038 (2.71)              |         |
| Jawf  | 1657 (1.62)                                | 152 (1.53)                         | 1809 (1.61)              |         |
| Jazan   | 3807 (3.72)                                | 400 (4.03)                         | 4207 (3.75)              |         |
| Almadinah Almunawwarah                          | 6100 (5.96)                                | 626 (6.31)                         | 6726 (6.00)              |         |
| Makkah  | 26,219x (25.64)                            | 2580 (26.00)                       | 28,799 (25.67)           |         |
| Najran  | 1304 (1.28)                                | 130 (1.31)                         | 1434 (1.28)              |         |
| Alqassim  | 5016 (4.90)                                | 508 (5.21)                         | 5524 (4.92)              |         |
| Tabuk   | 3364 (3.29)                                | 319 (3.22)                         | 3683 (3.28)              |         |
| <b>Outcome</b>                                  |  |                                    |                          |         |
| Alive   | 100,608 (98.38)                            | 9734 (98.11)                       | 110,342 (98.35)          | 0.041   |
| Dead  | 1658 (1.62)                                | 188 (1.89)                         | 1846 (1.65)              |         |
| The average number of injured per traffic crash | 1.83                                       | 1.73                               | 1.82                     | <0.01   |

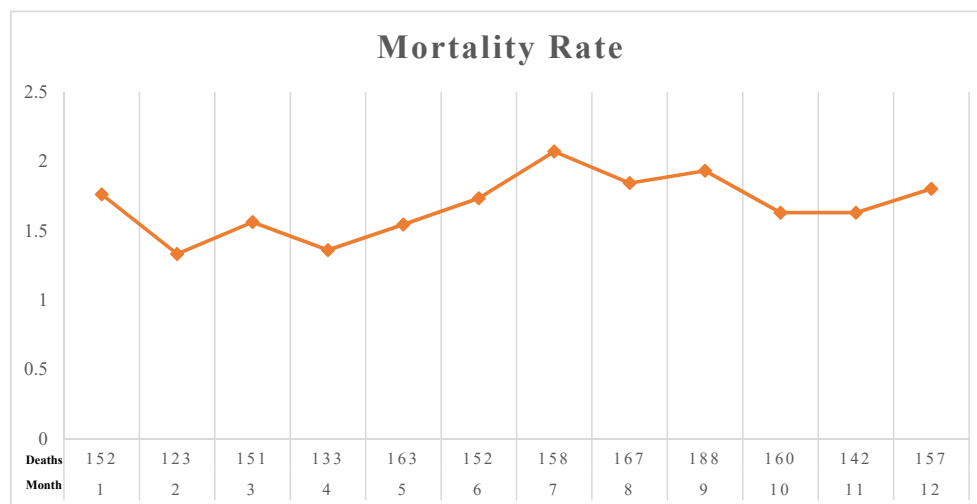


Figure 1: Number of deaths and mortality rate across the year 2021.

Table 2: The prevalence of injuries reported during sunset time across time periods.

| Time of Injury                | Injured in Other Months<br>N (%) | Injured in Ramadan<br>N (%) | Total<br>N (%)   | P-value |
|-------------------------------|----------------------------------|-----------------------------|------------------|---------|
| <b>All regions</b>            |                                  |                             |                  |         |
| Other time                    | 80,244 (78.47)                   | 7494 (75.53)                | 87,738 (78.21)   | <0.01   |
| Sunset time                   | 22,022 (21.53)                   | 2428 (24.47)                | 24,450 (21.79)   |         |
| Total                         | 102,266 (100.00)                 | 9922 (100.00)               | 112,188 (100.00) |         |
| <b>Riyadh</b>                 |                                  |                             |                  |         |
| Other time                    | 23,267 (80.48)                   | 2092 (78.00)                | 25,359 (80.27)   | <0.01   |
| Sunset time                   | 5642 (19.52)                     | 590 (22)                    | 6232 (19.73)     |         |
| Total                         | 28,909 (100.00)                  | 2682 (100.00)               | 31,591 (100.00)  |         |
| <b>Northern Borders</b>       |                                  |                             |                  |         |
| Other time                    | 888 (78.79)                      | 78 (63.41)                  | 966 (77.28)      | <0.01   |
| Sunset time                   | 239 (21.21)                      | 45 (36.59)                  | 284 (22.72)      |         |
| Total                         | 1127 (100.00)                    | 123 (100.00)                | 1250 (100.00)    |         |
| <b>Asir</b>                   |                                  |                             |                  |         |
| Other time                    | 7141 (78.62)                     | 614 (72.07)                 | 7755 (78.06)     | <0.01   |
| Sunset time                   | 1942 (21.38)                     | 238 (27.93)                 | 2180 (21.94)     |         |
| Total                         | 9083 (100.00)                    | 852 (100.00)                | 9935 (100.00)    |         |
| <b>Bahah</b>                  |                                  |                             |                  |         |
| Other time                    | 1395 (76.73)                     | 158 (83.16)                 | 1553 (77.34)     | <0.01   |
| Sunset time                   | 423 (23.27)                      | 32 (16.84)                  | 455 (22.66)      |         |
| Total                         | 1818 (100.00)                    | 190 (100.00)                | 2008 (100.00)    |         |
| <b>Eastern Region</b>         |                                  |                             |                  |         |
| Other time                    | 8749 (78.84)                     | 841 (77.37)                 | 9590 (78.71)     | 0.25    |
| Sunset time                   | 2348 (21.16)                     | 246 (22.63)                 | 2594 (21.29)     |         |
| Total                         | 11,097 (100.00)                  | 1087 (100.00)               | 12,184 (100.00)  |         |
| <b>Hail</b>                   |                                  |                             |                  |         |
| Other time                    | 2138 (77.32)                     | 200 (73.26)                 | 2338 (76.96)     | 0.12    |
| Sunset time                   | 627 (22.68)                      | 73 (26.74)                  | 700 (23.04)      |         |
| Total                         | 2765 (100.00)                    | 273 (100.00)                | 3038 (100.00)    |         |
| <b>Jawf</b>                   |                                  |                             |                  |         |
| Other time                    | 1282 (77.37)                     | 106 (69.74)                 | 1388 (76.73)     | 0.03    |
| Sunset time                   | 375 (22.63)                      | 46 (30.26)                  | 421 (23.27)      |         |
| Total                         | 1657 (100.00)                    | 152 (100.00)                | 1809 (100.00)    |         |
| <b>Jazan</b>                  |                                  |                             |                  |         |
| Other time                    | 2905 (76.31)                     | 282 (70.50)                 | 3187 (75.75)     | 0.01    |
| Sunset time                   | 902 (23.69)                      | 118 (29.50)                 | 1020 (24.25)     |         |
| Total                         | 3807 (100.00)                    | 400 (100.00)                | 4207 (100.00)    |         |
| <b>Almadinah Almunawwarah</b> |                                  |                             |                  |         |
| Other time                    | 4676 (76.66)                     | 473 (75.56)                 | 5149 (76.55)     | 0.53    |
| Sunset time                   | 1424 (23.34)                     | 153 (24.44)                 | 1577 (23.45)     |         |

**Table 2** (continued)

| Time of Injury  | Injured in Other Months | Injured in Ramadan | Total           | P-value |
|-----------------|-------------------------|--------------------|-----------------|---------|
|                 | N (%)                   | N (%)              | N (%)           |         |
| Total           | 6100 (100.00)           | 626 (100.00)       | 6726 (100.00)   |         |
| <b>Makkah</b>   |                         |                    |                 |         |
| Other time      | 20,444 (77.97)          | 1942 (75.27)       | 22,386 (77.73)  | 0.02    |
| Sunset time     | 5775 (22.03)            | 638 (24.73)        | 6413 (22.27)    |         |
| Total           | 26,219 (100.00)         | 2580 (100.00)      | 28,799 (100.00) |         |
| <b>Najran</b>   |                         |                    |                 |         |
| Other time      | 980 (75.15)             | 90 (69.23)         | 1070 (74.62)    | 0.13    |
| Sunset time     | 324 (24.85)             | 40 (30.77)         | 364 (25.38)     |         |
| Total           | 1304 (100.00)           | 130 (100.00)       | 1434 (100.00)   |         |
| <b>Alqassim</b> |                         |                    |                 |         |
| Other time      | 3800 (75.76)            | 377 (74.21)        | 4177 (75.62)    | 0.44    |
| Sunset time     | 1216 (24.24)            | 131 (25.79)        | 1347 (24.38)    |         |
| Total           | 5016 (100.00)           | 508 (100.00)       | 5524 (100.00)   |         |
| <b>Tabuk</b>    |                         |                    |                 |         |
| Other time      | 2579 (76.66)            | 241 (75.55)        | 2820 (76.57)    | 0.65    |
| Sunset time     | 785 (23.34)             | 78 (24.45)         | 863 (23.43)     |         |
| Total           | 3364 (100.00)           | 319 (100.00)       | 3683 (100.00)   |         |

Regarding the specific time of RTIs, all Saudi regions had higher percentages of RTIs during the sunset time of Ramadan as compared to the other months (24.5% vs. 21.5%;  $P < .01$ ). Northern borders had the highest percentage of RTIs during the sunset time of Ramadan than in other months (36.6% vs. 21.2%;  $P < .01$ ), followed by Jawf (30.3% vs. 22.6%;  $P = .03$ ), Asir (27.9% vs. 21.4%;  $P < .01$ ), Jazan (29.5% vs. 23.7%;  $P = .01$ ), Makkah (24.7% vs. 22%;  $P = .02$ ) and Riyadh (22% vs. 19.5%;  $P < .01$ ). On the other hand, Baha region had the lowest percentage of sunset RTIs in Ramadan compared to other months (16.8% vs. 23.3%;  $P < .01$ ). There were no significant differences in the time of RTIs transported by the SRCA in the other regions (Table 2).

Results from the logistic regression of the association between the RTIs occurring in Ramadan during the sunset time indicated that the Northern borders region had the highest odds of the RTIs occurring during the sunset time of

Ramadan as compared to the other times of the day with over two-folds (OR: 2.14; 95% CI: 1.44–3.17;  $P < .001$ ) followed by Jawf (OR: 1.48; 95% CI: 1.03–2.13;  $P = .03$ ), Asir (OR: 1.43; 95% CI: 1.21–1.66;  $P < .001$ ), and Jazan (OR: 1.35; 95% CI: 1.07–1.69;  $P = .01$ ). Furthermore, there were also 16% higher odds of the RTIs occurring during the sunset time of Ramadan as compared to the other times of the day in both Riyadh (OR: 1.16; 95% CI: 1.05–1.28;  $P < .001$ ) and Makkah (OR: 1.16; 95% CI: 1.05–1.27;  $P < .001$ ). In contrast, the Bahah region had 33% fewer odds of the RTIs occurring during the sunset time of Ramadan as compared to the other times of the day (OR: 0.67; 95% CI: 0.44–0.99;  $P = .05$ ). The associations between Ramadan and RTIs at sunset were not significant for the other regions, including Najran, Hail, Eastern province, Alqassim, Almadinah Almunawwarah, and Tabuk (Table 3).

## Discussion

Our study found that RTIs occur more frequently at sunset during Ramadan than the rest of the year, and that varies by region. The RTI rates were higher during Ramadan prior to the sunset in multiple regions around the Kingdom, including the Northern Borders, Asir, Jawf, Jazan, and Makkah. Notably, the Northern Borders region had the highest odds of RTIs before the sunset as compared to other times during the day. Furthermore, RTIs-related death rates were slightly higher during Ramadan than during the rest of the year.

Our findings are comparable to previous studies from Pakistan, Turkey, and United Arab Emirates (UAE).<sup>7,19,20</sup> In particular, Mehmood et al.<sup>19</sup> reported higher rates of RTIs during the early evening of Ramadan compared to other times of the day. Regarding death rates, Mehmood et al.<sup>19</sup> and Kalafat et al.<sup>7</sup> both found RTIs-related death rates were higher in Ramadan (4.1% and 1.5%, respectively) as compared to the other months (3.5% and 1.2%, respectively). The latter estimate was comparable to the death rates

**Table 3: Estimated odds ratios (OR) and 95% confidence intervals (CI) from a logistic regression model of the association between Ramadan and the likelihood that the injury occurs at sunset.**

| Region                 | Odds ratio | 95% CI    | P-value |
|------------------------|------------|-----------|---------|
| Riyadh                 | 1.16       | 1.05–1.28 | <0.01   |
| Northern Borders       | 2.14       | 1.44–3.17 | <0.01   |
| Asir                   | 1.43       | 1.21–1.66 | <0.01   |
| Bahah                  | 0.67       | 0.44–0.99 | 0.05    |
| Eastern R              | 1.09       | 0.93–1.26 | 0.26    |
| Hail                   | 1.24       | 0.93–1.65 | 0.13    |
| Jawf                   | 1.48       | 1.03–2.13 | 0.03    |
| Jazan                  | 1.35       | 1.07–1.69 | 0.01    |
| Almadinah Almunawwarah | 1.06       | 0.87–1.28 | 0.54    |
| Makkah                 | 1.16       | 1.05–1.27 | <0.01   |
| Najran                 | 1.34       | 0.90–1.99 | 0.14    |
| Alqassim               | 1.09       | 0.88–1.33 | 0.44    |
| Tabuk                  | 1.06       | 0.81–1.38 | 0.65    |

from our study, where we found 1.8% during Ramadan compared to 1.6% in the rest of the year.

Several mechanisms may be responsible for the increased RTIs and RTIs-related death during Ramadan. In Ramadan, particularly during the late afternoon, a decline in the body functions associated with fatigue, impaired cognitive function, and sleepiness accompanied by increased irritability and mood changes has been observed.<sup>21–24</sup> Gulek recently suggested that RTIs are likely caused by hunger when examining the impact of hunger, dehydration, and lack of sleep-related to traffic crashes.<sup>8</sup> Other studies still argue hunger might not only be the only factor. Boukhris et al.<sup>21</sup> reported significant decreases in sleep quantity and mental alertness as well as significant increases in fatigue and muscle soreness during Ramadan as compared to before Ramadan. Furthermore, Waterhouse et al.<sup>22</sup> found significant daytime napping and fatigue increases during Ramadan but did not link that to RTIs. Significant declines in visual learning and memories during the late afternoon in Ramadan were also reported by Tian et al.<sup>23</sup>

Another potential reason for the increased RTIs during Ramadan in SA may be the drivers' behaviors. A study from Turkey<sup>11</sup> reported that using a seatbelt is less common in Ramadan than in other months. They also found that horn honking is more prevalent during Ramadan than in other months.<sup>11</sup> Such behavior may lead to increased irritability, especially if accompanied by extreme hunger. Another driver behavior observed during Ramadan was speeding, which it was found to be responsible for 38% of the road traffic crashes in Pakistan.<sup>25</sup>

The holy month of Ramadan is a religious observation, some of which is considered a holiday. In addition, the working hours are reduced for employees and students, and many employees take a vacation during Ramadan. Several studies have found an increase in road traffic crashes during holidays regardless of whether in Ramadan for Muslims or other holidays for other religions.<sup>26–28</sup> In Pakistan, Kumar et al.<sup>27</sup> found that Ramadan and Eid Al-Fitr had the highest road traffic accidents in all 2014 years. Furthermore, higher odds of car crashes were observed during public holidays, particularly Christmas day, in the United Kingdom.<sup>28</sup>

The variation in sunset crashes between regions deserves some attention. While the Northern Borders had the highest odds of RTIs before the sunset, the opposite trend was observed in Bahah. It is unclear what is the reason for that and certainly is worthy of further research. One of the potential factors is increased migration to areas such Bahah during Ramadan. If true, it is likely that this will result in increased traffic in that area, which reduces the likelihood to speed. As a result, the risk for RTIs may decline during that period. More investigation into the contributing factors is needed to further understand the observed pattern.

This present study sheds light on the burden of RTIs in SA during Ramadan. Generally, the Kingdom has higher rates of RTIs than the majority of the countries worldwide.<sup>29</sup> Furthermore, a recent study by Alghnam et al.<sup>30</sup> has highlighted the significant economic burden of RTIs in the

Kingdom. In 2010, the Saudi government implemented an advanced surveillance system to detect traffic violations, which positively impacted RTI rates in the following years, particularly in the Riyadh region.<sup>31</sup> In this present study, we found that other regions than Riyadh had the highest odds of RTIs during the sunset, suggesting that the reinforcement of traffic laws is lacking in these regions compared to Riyadh. Therefore, more efforts on traffic law reinforcement and awareness programs should be directed to the other regions around the Kingdom. A reduction in the RTIs was observed after Vision 2030 was inaugurated.<sup>32</sup> Hopefully, such a decline will continue in the next upcoming years during the whole year, including the holy month of Ramadan.

Despite the large sample size in this study, it has several limitations. First, many key-related variables are not provided in this data. For example, risk factors including seatbelt use, speed, and vehicle equipment such as airbags are not captured. Other missing variables include environmental factors, which may act as confounding variables. Moreover, the data is missing on severity (i.e., injury severity score) and outcome after reaching the hospital, as well as comorbidities such as diabetes and hypertension, all of which may have contributed to the health outcomes of RTIs.<sup>33</sup> Second, these reported RTIs were from crashes observed by the SRCA at the crash scene; hence, RTIs from minor crashes that did not require prehospital transportation by ambulance were not included. Third, we were unable to compare RTIs that occurred on weekends with those during weekdays. The effect of Ramadan may have differed across regions or around time. Finally, deaths reported in this analysis occurred at the crash scene. Thus, we have no further fatality or severity information about those who were delivered to the hospital. However, this would be true during Ramadan and other months as well, and its effect on our overall findings would be minimal. Despite these limitations, this study is the largest analysis of the epidemiology of RTIs in Ramadan in the Kingdom and highlights the burden of RTIs on population health.

## Conclusions

This present study provides an insight into the burden of RTIs during Ramadan, particularly during sunset time. We recommend intensifying law reinforcement at sunset during Ramadan, especially in the other regions around the Kingdom with the highest burden. Also, we recommend designing an awareness campaign taking place before Ramadan to improve traffic safety. Finally, future studies should consider a systematic follow-up for the RTIs in the hospital to determine the fatality rate and the severity levels to design and evaluate appropriate interventions.

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## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The study was reviewed and approved by the Institutional Review Board (IRB) of the SRCA (No 21-E1-Dated: 12/09/2021).

## Authors contributions

YA, SA conceived the study design, drafted the method section and analyzed the data. RA wrote the introduction section. BA wrote the results section. SMA wrote the discussion section. FA and JA provided logistic support and critical review of the study. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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