International Journal of Paramedicine

Published by the National EMS Management Association (USA)

RESEARCH REPORT

NAVIGATING PARAMEDICS' SAFETY: UNRAVELING FACTORS IN EMERGENCY SERVICE VEHICLE INCIDENTS

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Recommended Citation: Delavary, M., Tremblay M., & Lavallière M. (2024). Navigating paramedics' safety: Unraveling factors in emergency service vehicle incidents. *International Journal of Paramedicine*. (5), 82-102. https://doi.org/10.56068/MHCE4982. Retrieved from https://internationaljournalofparamedicine.com/index.php/ijop/article/view/2755.

Keywords: ambulance crashes; drivers' characteristics, environment, emergency/non-emergency activities, work-related collisions, emergency medical services, paramedicine

Received: April 20, 2023
Revised: October 29, 2023
Accepted: October 29, 2023
Published: January 5, 2024

Funding: External funding was not used to support this work.

Declaration of Interests: No competing interests.

Acknowledgements: The authors would like to acknowledge the collaboration of Urgences-santé and the Société de l'assurance automobile du Québec for their contribution and for providing data on this crucial topic in road safety.

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ABSTRACT

Problem: First responders form a critical cornerstone of public health, providing rapid and lifesaving medical assistance. However, paramedics are at a persistent elevated rate of collisions while in displacement compared to workers who drive vehicles of similar size and other professional drivers. This highlights a pressing concern that necessitates investigation.

Study Objective: This study is a retrospective study aimed to describe factors involved in paramedics' collisions.

Method: Spanning over 10 years of data (2010-2019) from a paramedic agency covering Montreal (Qc, Canada), links between the number of ambulance injuries and non-injury collisions and diverse characteristics like experience, sex, and age of paramedics, locations, and driving activities. The distribution of characteristics involved in the severity of collisions is presented with descriptive analysis. The evaluation of trends of monthly and yearly ambulance collisions is conducted along a logit model to examine the effect of such factors on the odds of collision severity.

Results: The results indicate that there is no decline in the trend of monthly ambulance collisions. However, calculating the yearly occurrence of non-injury collisions per 10 paramedics shows a statistically significant decline. Young paramedics with less ambulance driving experience are more involved in multiple collisions compared to their experienced colleagues. Furthermore, 62% of injury collisions happen when paramedics are responding to an emergency call, confirmed by a decrease in the odds of injury collisions (0.48) during non-emergency activities. Intersections and traffic lights are the riskiest locations regarding injury collisions (43.5%, and 51%, respectively). Collisions occurring at traffic lights can increase the odds of severity by nearly six times.

Conclusion: This study exemplifies that preventive policy regarding paramedics should focus on younger paramedics, paramedics less experienced in operating the vehicles, and risky locations, especially while on emergency calls. More oriented programs for paramedics are required to reduce the number of collisions.

INTRODUCTION

Center for Disease Control and Prevention (CDC) (United States of America) and the World Health Organization (WHO) (Switzerland) declared that traffic collisions lead to the death of approximately 1.35 million people per year (Centers for Disease

Control Prevention, 2005, 2020; World Health Organization, 2020) from which 33% of drivers involved in these collisions are mostly considered as work-related collisions (European Agency for Safety and Health at Work (EU-OSHA), 2019). More specifically, work-related collisions among emergency respondents have been identified as the leading cause of mortality (Fetto Law Group, 2018; Lavallière, 2015). As per the American Ambulance Association data, there are an estimated 10,000 or more ambulance-related collisions annually, with many of these resulting in injury or death (US Fire Administration, 2014). More specifically, compared to overall traffic collisions, ambulance vehicles are 1.7 times more likely to be involved in fatal collisions and 1.9 times more likely to be involved in injury collisions (Chiu et al., 2018).

Each year, emergency medical responders in the United States (US) experience an average of ten transportation-related fatalities (Maguire, 2015). Between 2006 and 2008, paramedics in the US encountered a traffic collision risk that was five times greater than the national average (Maguire, 2011). Additionally, their rate of occupational fatalities and injuries related to transportation collisions exceed the national average (Maguire, 2015; Maguire, 2013). Most of the fatalities in this sector result from collisions related to transportation. Traffic collisions accounted for 74% of paramedics' fatalities, with medical emergency responders driving in 69% of these incidents (Maguire et al., 2002). Furthermore, compared to other vehicles of similar size and weight, ambulances are more frequently involved in collisions (Ray & Kupas, 2005; Sanddal et al., 2008).

As per the usage of lights and sirens, there were 7.0 collisions without lights and sirens and 17.1 with lights and sirens per 100,000 trips in 2016 in the US (Watanabe, Patterson, Kempema, Magallanes, & Brown, 2019). Jarvis et al. (2021) found that the utilization of lights and sirens is linked to a rise in collisions and injuries among paramedics. Consequently, there is a pressing need for a structured approach to emergency medical responders in developing specific strategies for responding with lights and sirens. This is because only a small percentage (6.9%) of responses involving lights and sirens need potentially life-saving interventions.

Furthermore, 99,400 injuries and 65 mortalities were recorded between 2003 and 2007 for paramedics and emergency respondents from the Bureau of Labor Statistics (BLS) (USA), which shows a higher rate compared to other kinds of workers (Reichard, Marsh, & Moore, 2011). In Quebec (Canada), there are 1228 ambulance collisions (including 5 fatalities, 344 injuries, and 859 non-injury) covering from 2010 to 2020 (Soci t de l'assurance automobile du Qu bec, 2020). In Turkey, 81.4% of paramedics (n=733) declared being in at least one collision while on duty in an ambulance (GŸlen et al., 2016). In Poland, there were five deaths and 153 injured people from January 2008 to December 2012 (Galazkowski, Binkowska, & Samolinski, 2015). It is clear that work-related collisions happen worldwide and that they are of utmost importance to address.

Some studies reviewed the characteristics of paramedics involved in collisions. For example, it is found that males are involved more than females in ambulance collisions (almost 80% vs. 20%) (Chiu et al., 2018; Custalow & Gravitz, 2004) but there has been an increasing trend in the proportion of females recently (Galazkowski et al., 2015). Also, younger drivers (under 30 years old) are more involved in ambulance collisions (Galazkowski et al., 2015) and a study stated that ambulance drivers, the mean age of 32 years old, who are responsible for collisions had a previous history of multiple collisions in 71% of the cases (Custalow & Gravitz, 2004).

There is a wide range of literature looking at ambulance collisions' characteristics like environmental factors or time of collisions. For instance, the probability of a collision happening is higher during daytime hours (0800 to 1200) and evening hours (1600 to 2000) compared to other periods throughout the day (Chiu et al., 2018; Drucker, 2013; Lai, Chou, & Chang, 2018). Also, it is reported that almost 33 % of all ambulance collisions happened on Friday (Biggers, Zachariah, & Pepe, 1996). Looking at the location of collisions shows that there is a significant number of collisions happening at intersections; for instance, a T-bone mechanism or striking a vehicle with an angle is found to be a highly frequent type of ambulance crash (Custalow & Gravitz, 2004; Kahn, Pirrallo, & Kuhn, 2001). A descriptive study showed five fatal collisions (out of eight) and 463 non-fatal collisions (out of 707) happened at four-point intersections in Taiwan from January 2011 to October 2016 (Chiu et al., 2018). Collisions are statistically more prone to happen at intersections (67% vs. 26%) or at stop signs or signals (53% vs. 14%) in urban environments compared to rural areas (Ray and Kupas, 2007). There are other studies supporting the fact that four way or more intersections, and with traffic signals can increase the risk of ambulance injury and non-injury collisions (Drucker, 2013; Pirrallo & Swor, 1994; Ray & Kupas, 2005). As per weather conditions, a study shows that most collisions happened when the atmospheric conditions are clear (79.8%) and roadways are dry (67.9%), and only a few of them occurred on snow or ice (5.5%) (Pirrallo & Swor, 1994). Overall, one can appreciate that there are numerous factors influencing the implication of paramedics in collisions and their effects on the severity of collisions.

PURPOSE AND OBJECTIVES

The purpose of the current study is to descriptively and statistically analyze the key characteristics surrounding ambulance collisions in Montréal, Canada, that are not typically documented on a formal road safety data set. In this case, most collisions in locations like parking lots, hospitals, etc. were provided by Corporation d'urgences-santé (CUS) and not available in the Société de l'assurance automobile du Québec (SAAQ) data set. To our knowledge, this study is the first of its kind to focus on collision characteristics, with a specific focus on paramedics' factors such as age, experience, sex, and collision history in Canada.

The study received ethical approval from both the University of Quebec at Chicoutimi (2019-131, 602.545.04) and CUS scientific review committees, ensuring adherence to the necessary ethical standards for research.

METHODS

Data Collection

This research is based on paramedics' collision data collected in a corporation of a metropolitan city (Montréal, Canada) coming from CUS dataset including 4,577 non-injury and 136 injury collisions from January 2010 to December 2019. The CUS serves as the official public emergency medical service for Montréal and Laval islands in the province of Quebec (Canada), providing a comprehensive repository of detailed collision data involving medical emergency vehicles in these areas (CUS, 2023). Also, the SAAQ administers driver's licenses, vehicle registration, and Quebec's public automobile insurance plan, making it a comprehensive source of detailed collisions data for the province (SAAQ, 2020).

Statistical Analysis

This study aimed to understand the effect of contributing factors on the severity of ambulance collisions. To quantify the odds ratio of being involved in an injury collision for each unit increase in an explanatory variable, such as the age or experience of paramedics, a multivariable logit model was employed using Stata software (StataCorp LLC, USA). The interpretation of the odds ratio is the probability of an event happening when the factor of interest is present, divided by the probability of the event occurring when the factor is absent. To illustrate, consider the odds ratio for the involvement of drivers over 25 in crashes compared to those aged 25 and below. If the younger drivers are on the baseline and the odds ratio for the older drivers is 0.70, the older drivers are 30% less likely to be involved in a crash. The linear relationship between the explanatory variables and a binary response variable, including injury and non-injury collisions can be written in the following equation. Note that p-values less than 0.05 shows the effect of explanatory variables is statistically significant at the 95th percentile confidence limit.

$$\ell = \mathrm{Log}\frac{P}{1-P} = \beta_0 + \beta_i X_i$$

Equation 1 - Where ℓ is the log-odds, X_i is the independent variable, and β are the coefficients of the parameters of the model (Ma, Shao, Yue, & Ma, 2009).

One of the main steps is a variable selection to use in logit regression. This study used the variance inflation factor (VIF) to check multicollinearity. VIF values above 5 indicate severe multicollinearity. So, if none of the explanatory variables in our models have a VIF over 5, it is assumed that multicollinearity is not an issue in our model. The existence of collinearity between variables rejects the assumption of independence. So, in such models, it is possible to estimate the parameters despite the collinearity, but the standard error will be inflated and, make it impossible to understand the importance and impact of each variable (Dormann et al., 2013).

The next step is examining the performance of the model by using measures such as a Receiver Operating Characteristic (ROC) curve. This is a graph that shows the performance of a classification model at all response thresholds. This graph is produced by plotting the true positive rates (y-axis) with the false positive rates (x-axis) (Markham, 2014). The ROC curve is an important indicator for evaluating the overall performance of the logit regression, which generally shows whether the true positive rate is higher than the false-positive rates. Area Under Curve of ROC Curve (AUC-ROC) shows the relationship between sensitivity and specificity. The value of this number is used to describe the overall performance of a classification model in which values close to 1 represent an accurate classification and values less than 0.5 are considered not acceptable (Mujalli, López, & Garach, 2016; Provost & Domingos, 2000). Furthermore, the other measurements to assess the goodness of fit is Pseudo R2 and correctly classified (%) values which measure the number of actual positives and negatives which are correctly classified. This study chooses the best-fitted model based on the maximum Pseudo R2, the area under the ROC curve, and correctly classified (%) values.

Additionally, Shewhart's control charts help us figure out if the variation in data is normal or caused by specific circumstances (Nolan et al., 2016; Perla et al., 2011). There are two types of reasons for such variations: common causes that happen naturally over time, and special causes that are not part of a system and happen because of specific circumstances. Shewhart's chart has three lines including the central line and upper and lower control limit lines and points plotted on a graph. If the points are plotted outside of control limit lines, there is a sign of special causes of variation in data. Control limits are typically set at a certain number of standard deviations from the process mean or centerline.

To assess the trend and changes within the studied datasets, the Mann-Kendall and Wilcoxon rank sum tests were employed, respectively. The null hypothesis for Mann Kendal test is that there is no decreasing/increasing trend and the null hypothesis for the Wilcoxon rank sum test is true location shift is equal to zero.

RESULTS

Descriptive Analysis

We cross-referenced the CUS data presented in Table 1 with the collision dataset from the SAAQ for the corresponding time frame and geographical region. This table shows the percentage of overlap for the same data (injury or non-injury collisions) in different source databases including CUS and SAAQ. For instance, in 2019, only 6.83% of all non-injury collisions were matched in both CUS and SAAQ and 88.78 were only available in the CUS dataset. This is because SAAQ primarily records severe collisions that result in injuries or fatalities.

There were 2.11% injury and 5.41% non-injury cases (out of total collisions) matched for both sources during the period from January 2010 to December 2019. Of these, 90.27% of non-injury collisions are only available in CUS datasets which means these are minor collisions that were only recorded internally. Additionally, the SAAQ dataset includes 0.6% injury and 1.4% non-injury collisions that were not present in the CUS dataset. These collisions were incorporated into the CUS data to create a comprehensive dataset for this study.

Year	Injury Collisions			Non-Injury Collisions		
	Available in both CUS and SAAQ	Available only in CUS	Available only in SAAQ	Available in both CUS and SAAQ	Available only in CUS	Available only in SAAQ
2010	4.19	0.44	1.10	4.86	86.31	3.09
2011	3.22	0.00	1.61	4.63	88.13	2.41
2012	1.94	0.39	0.39	5.81	89.73	1.74
2013	1.59	0.2	0.00	5.17	92.05	0.99
2014	2.07	0.00	0.62	6.22	90.25	0.83
2015	0.88	0.44	0.22	4.16	93.44	0.88
2016	1.24	0.00	0.41	3.91	93.83	0.62
2017	1.79	0.22	0.67	6.71	89.49	1.12
2018	1.95	0.00	0.22	5.84	90.69	1.30
2019	2.2	0.24	0.73	6.83	88.78	1.22
Mean	**2.11**	**0.19**	**0.60**	**5.41**	**90.27**	**1.42**

Table 1. Similarity between CUS and SAAQ sources (in percentage).

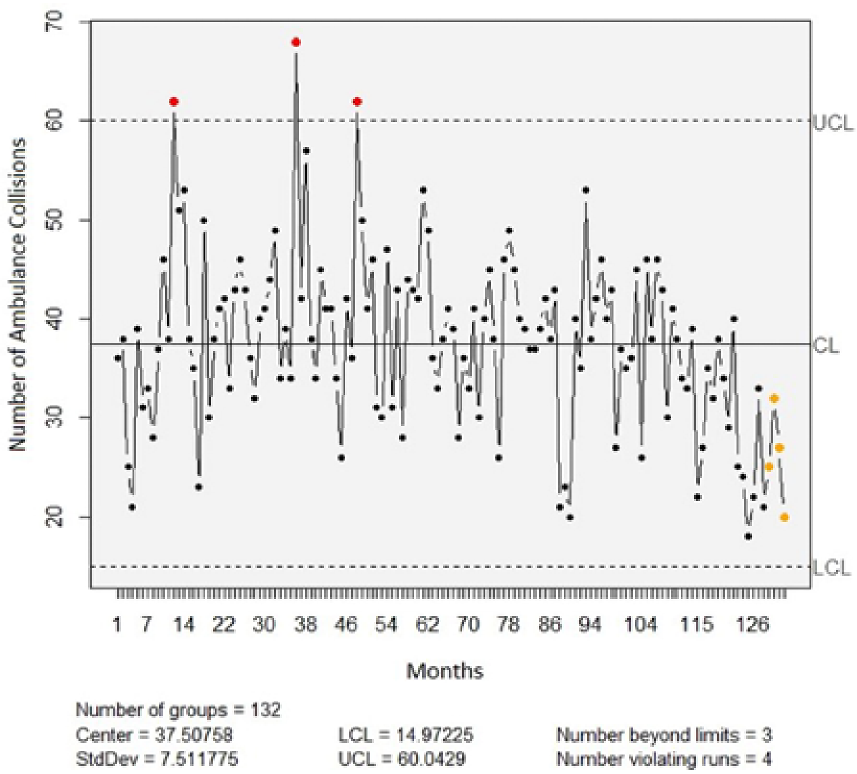


Figure 1. Shewhart Chart of Ambulance Monthly Collisions between January 2010 and December 2020 in Montreal, Quebec.

Figure 1 shows a Shewhart chart that tracks the monthly collisions involving ambulances from January 2010 to December 2020. The chart has a centerline at 37.5076, and there are lower and upper control limit lines, which are set at 14.9723 and 60.0429, respectively. Most of the data points on the chart cluster around the centerline, showing that the ambulance collisions are typically within a certain range. However, there are only three points that go beyond these control limits, indicating the possibility of outliers or special causes for these particular points. For analyzing the trend of ambulance monthly collisions visible in this Figure, the Mann Kendal test was also used. The result shows that no trend is found for this time series (p-value= 0.2746).

Also Figure 2 shows the incidence of yearly injury collisions per 10 paramedics and non-injury collisions per 10 paramedics covering from 2010 to 2019. The reason for presenting the incidence of injury collisions per 10 paramedics in Figure 2 is to aid visualization, as these types of collisions occur significantly less frequently than non-injury collisions. Although there is a significant drop (Wilcoxon rank test; p-value= 0.0495) after 2011 in the incidence of injury, there is no significant decrease in the overall trend (Mann Kendal test; p-value= 0.0736). Furthermore, there is a significant reduction trend (Mann Kendal test; p-value= 0.0123) for the incidence of non-injury collisions.

Distribution of injury and non-injury collisions during a week and along a day are shown in Figures 3 and 4. In this regard, the time-of-day variable was divided into 12 periods of 2 hours bins. The percentage of injury collisions from 20:00 to 21:59 and non-injury collisions from 16:00 to 17:59 are higher than other periods with 16.67% and 13.60%, respectively. And paramedic drivers were less involved in injury collisions (0.93%), and non-injury collisions (2.48%) from 4:00 a.m. to 5:59 a.m. Furthermore, the

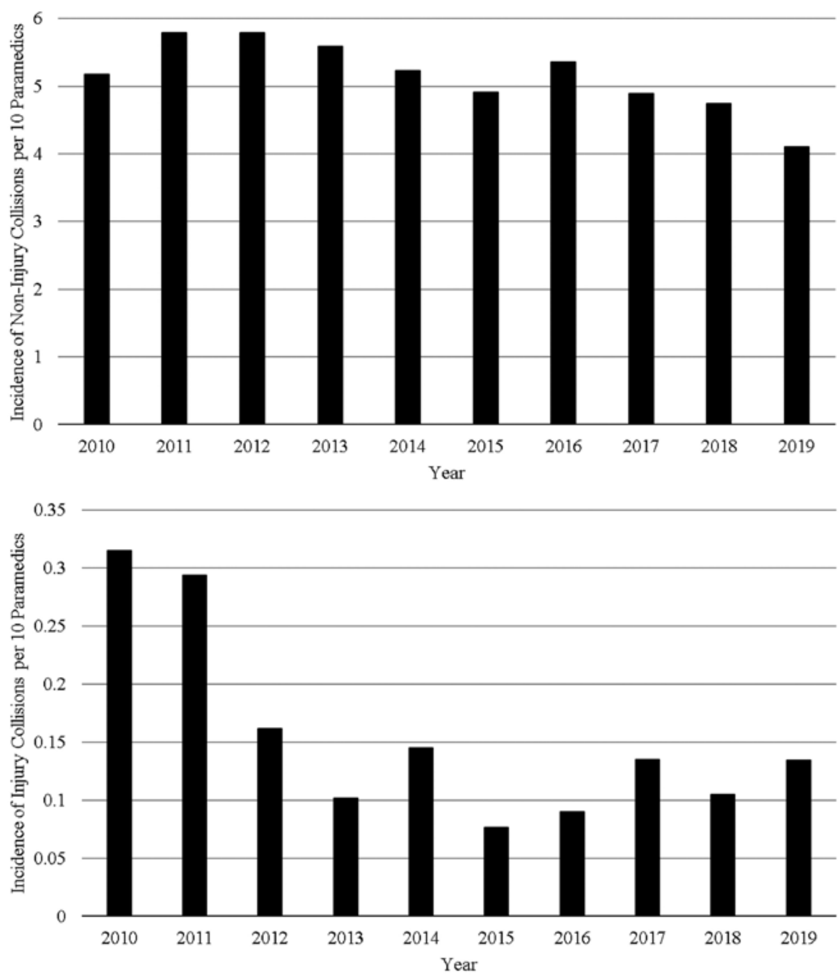


Figure 2. Incidence of Yearly Non-Injury (upper panel) and Injury (lower panel) Collisions between January 2010 and December 2020 in Montreal, Quebec.

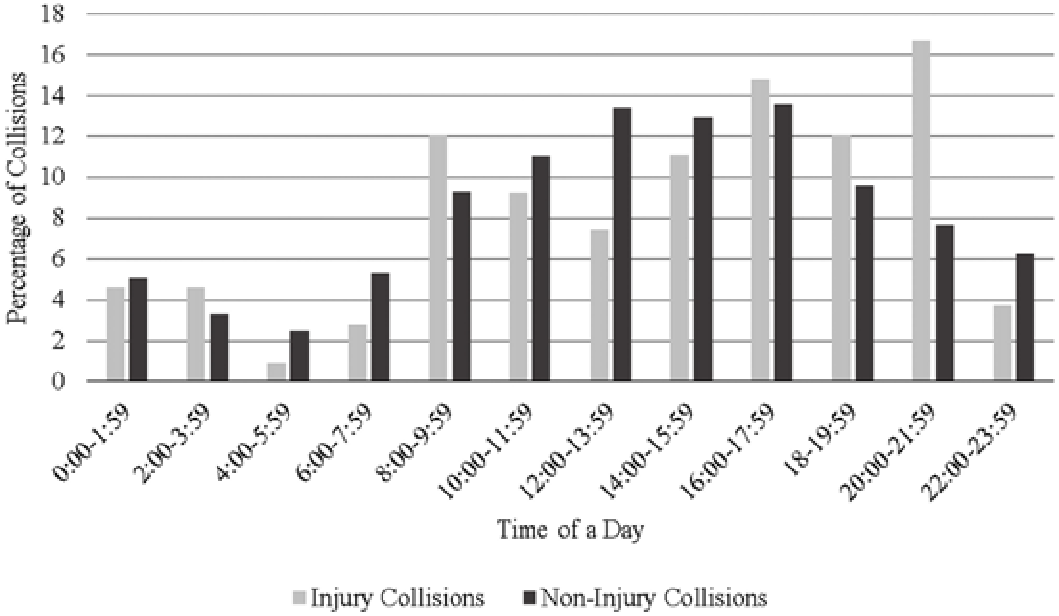


Figure 3. Distribution of collisions along a day.

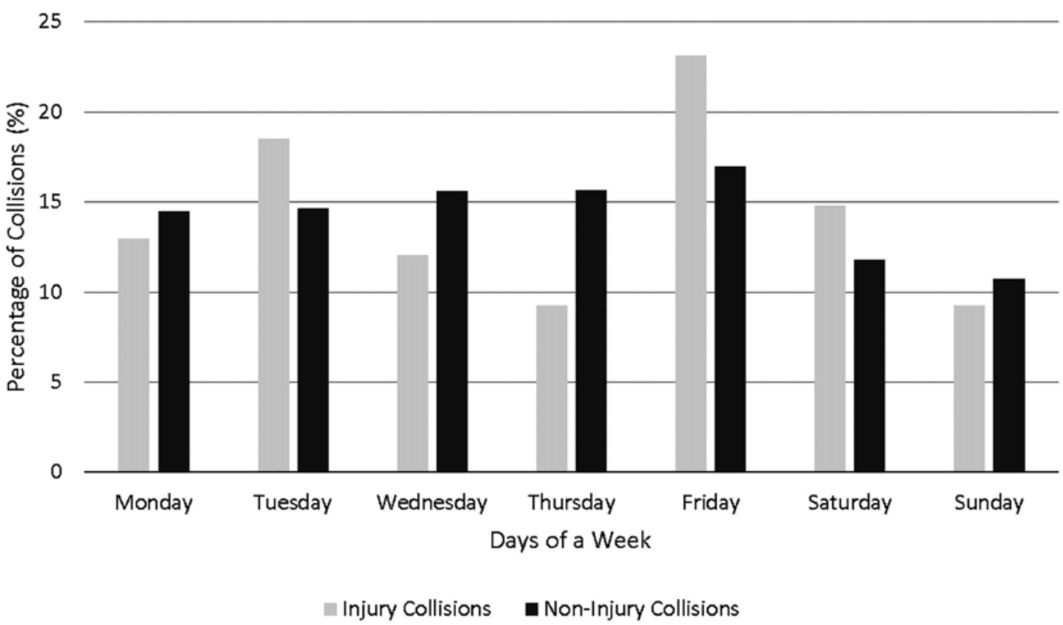


Figure 4. Distribution of collisions during a week.

pattern of non-injury collisions remains relatively constant throughout the week; however, injury collisions exhibit two spikes on Friday (23.15%) and Tuesday (18.52%). Friday has the highest number for both injury and non-injury collisions, counting 23.15% and 16.99% of the total, respectively.

Furthermore, the distribution of collisions severity (including injury and non-injury) among other variables like paramedic factors (e.g., experience, sex, and age of drivers), weather and surface conditions, environmental factors (e.g., type of environment, road topography, and signal type), day and time of the collision, and type of driving activity are shown in Table 2.

The number of male and female drivers involved in crashes is 3,672 and 961 cases, respectively. In detail, the number of injury collisions where males are involved is 78 more than females (93 vs. 15, respectively). The workforce consists of 27% females and 73% males in terms of gender distribution. In addition, there is no notable difference between male and female paramedics' involvement in non-injury collisions (0.50 vs. 0.53 collisions per paramedic, respectively). Also, the number of injury collisions per 10 paramedics is more for males compared to females (0.13 vs. 0.08, respectively).

Ambulance drivers between ages 25-45 are more involved in injury/non-injury collisions with 2,490 (out of 4,633) cases when compared to those outside this bracket. Moreover, paramedics aged 45 or older show a higher percentage of involvement in injury collisions (30.56%) compared to their younger counterparts aged 25 or less (12.04%). This might be due to a smaller number of staff aged less than 25 years old. Figure 5 shows a 3D distribution of the number of collisions per paramedic among different ages and experiences for both males and females. It shows that the number of young paramedics with low experience involved in multiple collisions is more than others. Additionally, there is a slight increase in the number of collisions among male paramedics over the age of 45.

Paramedic drivers with less than seven years of experience, most of them being younger, were involved in 2,437 collisions (2,384 non-injury and 53 injuries). Figure 5 shows a 3D plot to understand the intricate interplay between age, experience, and collision occurrences. By representing age and experience on the X and Y axes respectively, and collisions on the Z-axis, it aims to provide a comprehensive visual representation that not only showcases how collisions change with varying levels of experience and age but also highlights the joint impact of these variables on collision outcomes. According to this Figure, the number of collisions that involved paramedics ranging from seven to 20 years of experience reached 990 cases (963 non-injury and 27 injuries) and after that, it increased to 1206 collisions (1176 non-injury and 28 injuries) for paramedics with more than 20 years of experience, especially for male drivers.

In 23.82% (n: 1078) of non-injury and 19.44% (n: 21) of injury collisions, ambulance drivers were considered responsible for the collisions. And there is no clear answer for 66% of collisions on knowing who (civilian or ambulance drivers) is responsible for collisions. Furthermore, paramedic drivers with unknown use of seatbelts represent 2843 non-injury (62.83%) and 62 injuries (57.41%) crashes. The number of non-injury and injury collisions when they wear seatbelts is 1328 (29.35% of the total) and 41 (37.96% of the total), respectively.

In 37 injury cases (34.26%), the airbags were not deployed during the collisions, and for 67 cases, there is no answer on our database. This trend is observed for non-injury collisions with 1863 (41.17%) and 2645 (58.45%) cases for "not used" and "not answered" categories, respectively.

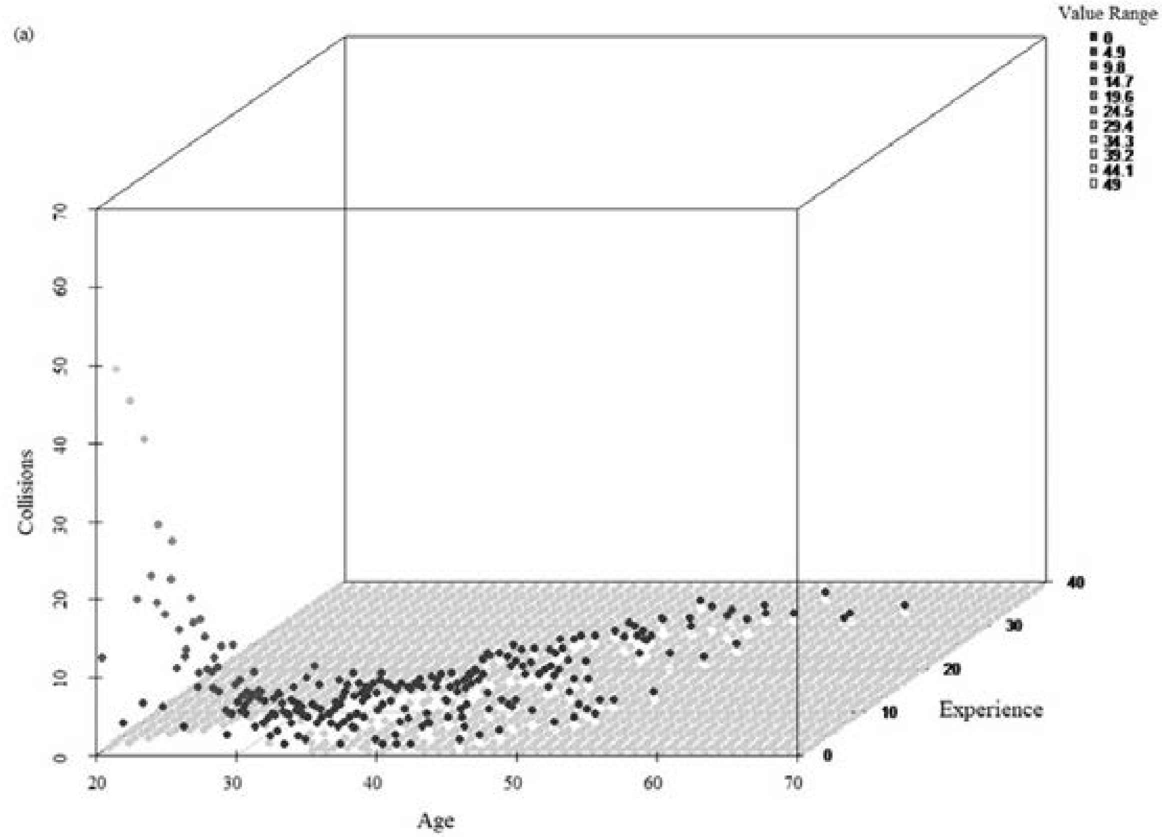
The driving activity was categorized into four groups: emergency driving (also known as the 10-30 code), non-emergency driving (also known as the 10-16 code), on-site, and others. In most of the cases in which the ambulance drivers were involved in the colli-

Variable	Category	Sub-Category	Non-Injury	Injury	Total
Paramedic Level Factors	Sex	Female	946 (20.91%)	15 (13.89%)	961
		Male	3579 (79.09%)	93 (86.11%)	3672
	Age	Less than 25	785 (17.35%)	13 (12.04%)	798
		Between 25 and 45	2428 (53.66%)	62 (57.41%)	2490
		More than 45	1312 (28.99%)	33 (30.56%)	1345
	Experience	Less than 7 year	2384 (52.69%)	53 (49.07%)	2437
		Between 7 and 20	963 (21.28%)	27 (25%)	990
		More than 20	1178 (26.03%)	28 (25.93%)	1206
	Responsibility	Yes	1078 (23.82%)	21 (19.44%)	1099
		No	406 (8.97%)	12 (11.11%)	418
		Shared	55 (1.22%)	2 (1.85%)	57
		Not answered	2986 (65.99%)	73 (67.59%)	3059
	Seatbelt	Yes	1328 (29.35%)	41 (37.96%)	1369
		No	354 (7.82%)	5 (4.63%)	359
		Not answered	2843 (62.83%)	62 (57.41%)	2905
	Localization	Rural	32 (0.71%)	0 (0.00%)	32
		Waiting area	38 (0.84%)	0 (0.00%)	38
		Operational Center	155 (3.43%)	0 (0.00%)	155
		Hospital	414 (9.15%)	0 (0.00%)	414
		Intersection	635 (14.03%)	47 (43.52%)	682
		Roadway between intersections	825 (18.23%)	23 (21.3%)	848
		Median strip	24 (0.53%)	1 (0.93%)	25
		Commercial Center	57 (1.26%)	0 (0.00%)	57
		Shoulder	67 (1.48%)	0 (0.00%)	67
		Land or private road	103 (2.28%)	0 (0.00%)	103
		Tunnel/Bridge	34 (0.75%)	0 (0.00%)	34
		Others and not answered	2141 (47.31%)	37 (34.26%)	2178
	Environment	Hospital	688 (15.2%)	0 (0.00%)	688
		Operation center	235 (5.19%)	0 (0.00%)	235
		Waiting area	65 (1.44%)	0 (0.00%)	65
		Residential	1224 (27.05%)	33 (30.56%)	1257
		Commercial	1243 (27.47%)	51 (47.22%)	1294
		Industrial	197 (4.35%)	5 (4.63%)	202
		Rural	239 (5.28%)	10 (9.26%)	249
		Others (e.g. school, park and parking lots) and not answered	634 (14.01%)	9 (8.33%)	643
	Road Topography	Flat/Straight	3431 (75.82%)	94 (87.04%)	3525
		Flat/Curve	213 (4.71%)	0 (0.00%)	213
		Hill/Straight	324 (7.16%)	7 (6.48%)	331
		Hill/Cruve	128 (2.83%)	3 (2.78%)	131
		Not answered	429 (9.48%)	4 (3.7%)	433
	Pavement Type	Asphalt	3789 (83.73%)	102 (94.44%)	3891
		Concrete	277 (6.12%)	1 (0.93%)	278
		Others (e.g. gravel)	459 (10.14%)	5 (4.63%)	464

Table 2. Descriptive analysis of ambulance collisions in Montreal from 2010 to 2019.

Variable	Category	Sub-Category	Non-Injury	Injury	Total
Paramedic Level Factors	Signalization	No Traffic light	2950 (65.19%)	33 (30.56%)	2983
		Traffic light	650 (14.36%)	55 (50.93%)	705
		Flashing red light	63 (1.39%)	2 (1.85%)	65
		Green light with priority	70 (1.55%)	2 (1.85%)	72
		Stop sign	57 (1.26%)	1 (0.93%)	58
		Obstacle(s) sign	716 (15.82%)	12 (11.11%)	728
		Others (e.g. pedestrian lights and flashing yellow light) and not answered	19 (0.42%)	3 (2.78%)	22
	Region	West	1829 (40.42%)	39 (36.11%)	1868
		East	2025 (44.75%)	38 (35.19%)	2063
		North	576 (12.73%)	30 (27.78%)	606
		Others	95 (2.1%)	1 (0.93%)	96
	Pavement Conditions	Good condition	3633 (80.29%)	97 (89.81%)	3730
		In Construction	148 (3.27%)	3 (2.78%)	151
		Under reparation	39 (0.86%)	1 (0.93%)	40
		Pot hole	143 (3.16%)	2 (1.85%)	145
		Others	562 (12.42%)	5 (4.63%)	567
Weather Conditions	Surface State	Dry	2710 (59.89%)	66 (61.11%)	2776
		Wet	609 (13.46%)	24 (22.22%)	633
		Snowy	488 (10.78%)	5 (4.63%)	493
		Icy	174 (3.85%)	4 (3.70%)	178
		Muddy & humid	67 (1.48%)	3 (2.78%)	70
		Others and not answered	477 (10.54%)	6 (5.56%)	483
	Weather Conditions	Black Ice	40 (0.88%)	0 (0.00%)	40
		Clear	2649 (58.54%)	66 (61.11%)	2715
		Covered	546 (12.07%)	13 (12.04%)	559
		Raining	256 (5.66%)	13 (12.04%)	269
		Snow/hail	231 (5.1%)	7 (6.48%)	238
		Gust of rain	87 (1.92%)	1 (0.93%)	88
		Strong winds	25 (0.55%)	1 (0.93%)	26
		Snowstorm	85 (1.88%)	0 (0.00%)	85
		Others (e.g. fog) and unknown	606 (13.39%)	7 (6.48%)	613
Vehicle	Airbag Used?	Yes	17 (0.38%)	4 (3.70%)	21
		No	1863 (41.17%)	37 (34.26%)	1900
		Not answered	2645 (58.45%)	67 (62.04%)	2712
Type of Task	Driving Activity	Emergency	1394 (30.81%)	67 (62.04%)	1461
		Non-emergency	1378 (30.45%)	22 (20.37%)	1400
		On-site	581 (12.84%)	1 (0.93%)	582
		Others	1172 (25.9%)	18 (16.67%)	1190
	Is there a Patient in the Ambulance?	Yes	1020 (22.54%)	33 (30.56%)	1053
		No	3017 (66.67%)	60 (55.56%)	3077
		Not answered	488 (10.78%)	15 (13.89%)	503

Table 2 (cont.). Descriptive analysis of ambulance collisions in Montreal from 2010 to 2019.



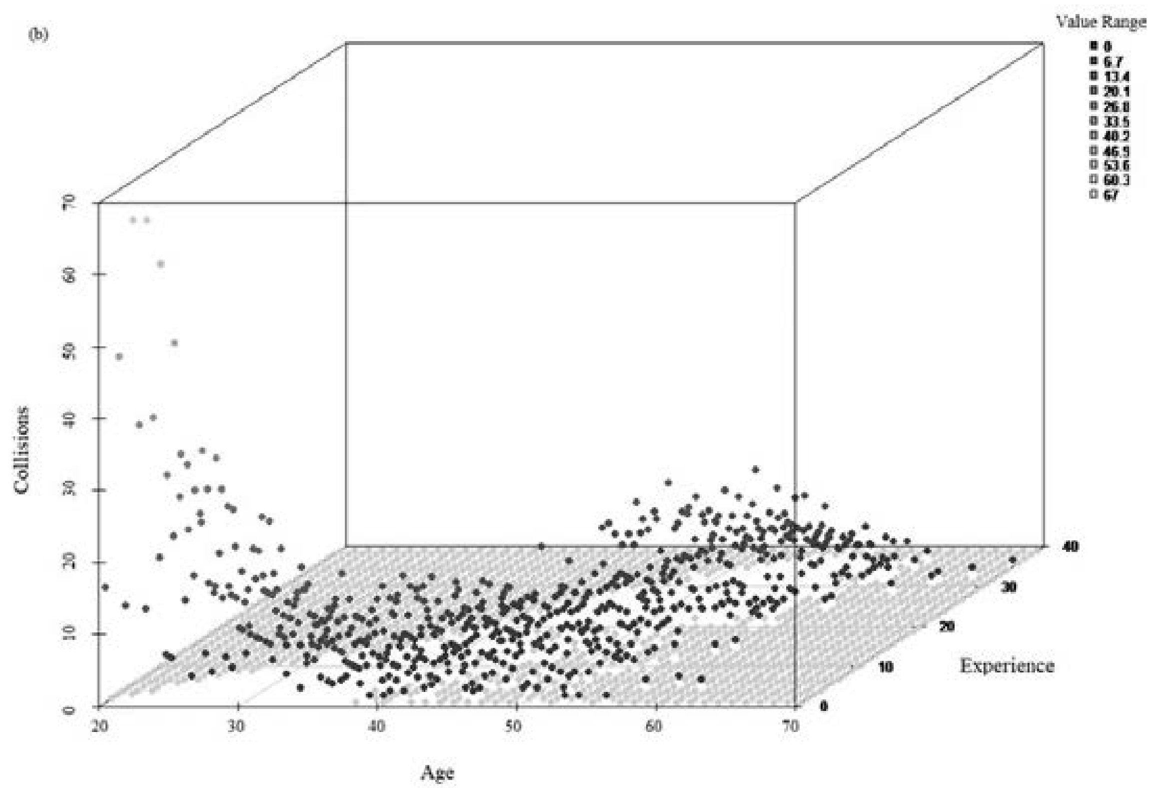


Figure 5. A 3D plot of collisions based on age and experience (a: female, b: male).

sion (especially for injury with 62.04% of total injury collisions), the crew was engaged in "emergency driving" with a total of 1,461 cases. Meanwhile, other levels of activity, including non-emergency driving, on-site, and others, had a total of 1400, 582, and 1190 cases, respectively. Also, there is no patient in the ambulance in 66.67% (n: 3,017) of non-injury and 55.56% (n: 60) of injury collisions.

In this study, four regions were used based on the Montréal Island: the north region, east region, west region, and other regions. The highest frequency of collisions can be seen in the east and the west regions of the territory with 2,063 and 1,868 cases, respectively. The north region exhibited 606 cases. Furthermore, there were more collisions reported in commercial and residential areas compared to other locations. Specifically, 1,294 collisions occurred in commercial areas, 1,257 in residential areas, and 688 in hospital areas. More precisely, intersections have the highest percentage of injury collisions (43.52%) compared to other areas like roadways between intersections (21.3%).

According to the weather conditions variables, the highest number of non-injuries (n: 2,649) and injury (n: 66) collisions happened when the sky was clear. In addition, 2776, 633, and 493 (out of 4633) collisions happened on a dry, wet, and snowy surface, respectively.

Flat/Straight areas exhibited 3,525 crashes, by far the largest number of cases of all areas, followed by Hill/Straight areas, which showed 331 cases. In addition, cases with no signalization showed 2950 (65.19%) cases, the largest number of cases in non-injury collisions, followed by cases with an obstacle sign, showing 716 (15.82%) cases. Traffic lights (n: 55) and no signalization (n: 33) are ranked in the top risky locations concerning injury collisions.

It should be mentioned that most collisions (n: 3,891) happened on asphalt pavement. Almost 81% of collisions happened when the pavement is in good condition. Only 336 crashes (7.25%) happened when the pavement is under construction, repair, or there are potholes on the pavement.

The effect of collision history on the total number of collisions for ambulance drivers during the studied period was examined with Pearson's product-moment correlation test. The null hypothesis of this test is that the true correlation is equal to zero. According to the results, there is a significant correlation (-0.383, 95%CI [-0.435, -0.327]; p-value< 0.0001) between the minimum interval separating individual paramedic's collisions and the overall number of collisions per ambulance driver. This means that by increasing the minimum interval of collisions, the total number of collisions per paramedic is expected to decrease. This trend is observed for the mean of intervals between collisions (-0.255, 95%CI [-0.313, -0.195]; p-value< 0.0001). In Table 3, the total number of collisions is presented for various interval cut-points, including the first to the fourth quartile of the minimum interval, as well as the mean of intervals between collisions for each ambulance driver. The results show that 36.5% and 24.91% of collisions are associated with drivers involved in collisions with a minimum interval of 28 days or less and a mean of intervals of 234 days or less.

Percentage	Minimum Interval				Mean Interval			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Cut-point of interval	28	85	283.5	2979	234.9	382	627.375	2979
Total number of collisions	1700	3042	4008	4657	1160	2651	3866	4657
Percentage (out of total collisions)	36.5	65.32	86.06	100	24.91	56.93	83.01	100

Table 3. Mean and Minimum of Intervals between collisions per ambulance driver.

Logit Regression

The logit regression results for the collision severity of ambulances are presented in Table 4. The VIF value for all variables used in this table is less than 5 which means there is no collinearity between variables. These tables provide the estimated odds ratios, standard error, z-value, p-values, and 95% confidence interval (CI) for each of the independent variables included in the models. The logit model demonstrated good performance as indicated by various goodness-of-fit measures such as Pseudo R2, the area under the ROC curve, and the percentage of correctly classified.

The models indicate that changing from emergency (baseline) to non-emergency, and on-site activities can lead to a reduction of 52% (95%CI; [75%, 6%]) and 92% (95%CI; [99%, 35%]) in odds of collision severity. “On-site activities” include tasks or operations that paramedics engage in at locations where the mission does not involve an emergency response. For example, collisions might occur in a hospital parking lot during non-emergency actions or at the CUS's vehicle depot.

Variables	Levels	Odds Ratio	Standard error	z-value	p-value	95% Confidence Interval	Pseudo R2	Area under ROC curve	Correctly classified
Activity	2	0.48	0.16	-2.15	0.03	[0.25, 0.94]	0.25	0.82	77.84%
	3	0.08	0.09	-2.36	0.02	[0.01, 0.65]			
	4	0.47	0.17	-2.03	0.04	[0.23, 0.97]			
Region	2	0.98	0.32	-0.07	0.94	[0.52, 1.85]			
	3	4.58	1.80	3.86	0.00	[2.12, 9.90]			
	4	0.21	0.26	-1.29	0.20	[0.02, 2.24]			
Surface Condition	2	1.47	0.55	1.03	0.30	[0.71, 3.05]			
	3	0.27	0.18	-1.99	0.05	[0.08, 0 .98]			
	4	1.13	0.83	0.17	0.87	[0.27, 4.78]			
	5	3.99	4.11	1.34	0.18	[0.53, 30.07]			
	6	0.66	0.46	-0.59	0.56	[0.17, 2.62]			
Signalisation	2	6.97	2.30	5.70	0.00	[3.58, 13.60]			
	3	0.87	0.82	-0.15	0.88	[0.14, 5.56]			
	4	3.08	3.10	1.11	0.27	[0.43, 22.24]			
	5	1.20	1.65	0.13	0.90	[0.08, 17.91]			
	6	2.10	1.17	1.33	0.19	[0.70, 6.27]			
	7	22.33	26.22	2.65	0.01	[2.24, 223.01]			

Table 4. Results of logit regression.

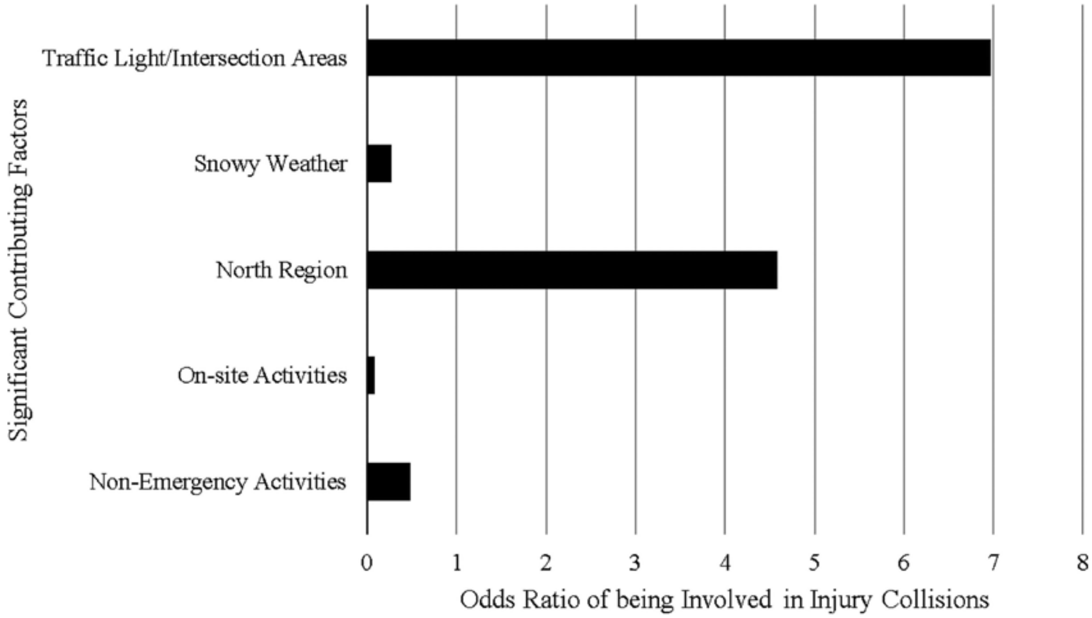


Figure 6. Summary of the effect of significant contributing factors on injury collisions.

Furthermore, trips in the north of Montréal lead to a high odds ratio (4.58, 95%CI; [2.12, 9.90]) compared to the other regions. The snowy surface is associated with a 73% (95%CI; [92%, 2%]) reduction in the odds of having an injury collision. Intersections with traffic lights can increase the odds of having a collision severity by 5.97 times (95%CI; [2.58, 12.60]) compared to no traffic light locations. The visual representation of the effect of these significant contributing factors on injury collisions is evident in Figure 6.

DISCUSSION

The primary focus of this study was to ascertain the factors contributing to the severity of work-related collisions within a paramedic corporation operating in the Montréal area (Quebec, Canada). The present results show that most ambulance collisions happen in urban environment areas such as commercial and residential. A study looking at ambulance collisions concluded that 82% of collisions occurred in an urban environment (Sanddal, Sanddal, Ward, & Stanley, 2010). Looking in detail, intersections have been identified as particularly risky locations, and the presence of traffic lights may increase the likelihood of injury collisions occurring. This is in line with multiple studies that worked on the location of collisions regarding emergency responders (Chiu et al., 2018; Custalow & Gravitz, 2004; Kahn, Pirrallo, & Kuhn, 2001; Lai et al., 2018; Pirrallo & Swor, 1994; Ray & Kupas, 2005). They confirmed that such locations are significant predictors of collisions and ambulances were more likely to be involved in them compared to others.

The date and time of collisions are associated with the frequency of ambulance collisions which is in line with the finding of Ray and Kupas (2005). Furthermore, the prevalence of non-injury and injury collisions is higher in the afternoon (23.82%; 12:00 to 15:59) and evening (26.85%; 16:00 to 19:59), respectively, which is consistent with other studies on the topic (Chiu et al., 2018; Drucker, 2013; Lai et al., 2018). This may be attributed to a variety of factors, such as the increased volume of emergency calls received during those times, as well as the heavier traffic on the roads, which can increase the likelihood of occurring a collision.

In more than 50% of collisions, ambulances did not have patients on board at the time of the collisions which is found in other literature (Sanddal et al., 2010). In addition, this study found that emergency activities can result in increasing the odds of collision's severity. Notably, the models indicate that changing from emergency to non-emergency, and on-site activities can substantially reduce the odds of collision severity. There are significant studies that concluded using lights and sirens or emergency mode can increase both frequency and severity of collisions. In this regard, there is a study that shows half of the collisions happened while using lights and sirens but did not find an association between emergency activities and an increase in the severity of the collisions (Biggers et al., 1996). This study shows most collisions happened in clear weather conditions and on dry surfaces. This fact is in line with previous literature about the effect of weather variables on ambulance collisions (Kahn et al., 2001; Pirrallo & Swor, 1994). However, it is found that the snow surface is associated with a reduction in the odds of having an injury collision. This might be due to a small proportion of calls or fewer crashes occurring in such kind of weather (Pirrallo & Swor, 1994). This could also be associated with an increased level of vigilance and preventive actions from paramedics while driving in such conditions, and thus to an overall reduction of collisions in such weather (Wilde, 1989).

Furthermore, it is found that cases with unknown seatbelt usage have a higher number of collisions for paramedics with 2,905 cases (out of 4,633), followed by those who wear it with 1,369 cases. This founding was reported in another study (Bentley & Levine, 2016). It is declared that 65.1% of paramedics were wearing seat belts when sitting in the front seat of the ambulance while 75.8% of their organizations have a written seat belt policy. And, almost no one (3.1%) during emergency mode reported using seat belts when in the patient compartment (Bentley & Levine, 2016). It is found that the chance of being killed or injured is significantly reduced by 3.77 times and 6.49 times, respectively, for ambulance occupants who are properly restrained (Becker et al., 2003). Therefore, specific interventions should be tailored to address this issue among paramedics since using seatbelts can improve the safety of both paramedics and civilian drivers. Moreover, one might assume that if the status of the seatbelt is identified as "unknown" while reporting the event, it is probably because it was not worn at the time of the collision.

Males were more involved in collisions compared to females (3672 vs. 961, respectively) which differs from a study with Maguire (Maguire, 2011) in terms of sex in paramedics' collisions (female: 53%). Or another study concluded that although females consist up 27% of employment, they were involved in 53% of collisions (Maguire, 2011). But the results of the study conducted by Boufous et al. (Boufous & Williamson, 2006) and Bellavance et al. (Bellavance, 2016) in terms of prevalence by sex in work-related collisions and other general kinds of literature on traffic safety confirm our findings (Choi, 2010; Claret et al., 2003; Durak, Fedakar, Türkmen, Akgöz, & Baduro lu, 2008; Mascarenhas et al., 2016). These results differ from the ones observed by Bellavance et al. (Bellavance, 2016) in terms of prevalence by sex in work-related collisions.

Furthermore, paramedics are more involved in collisions when they are young and have a lower level of experience, consistent with the general literature on road safety (Lloyd, Wilson, Mais, Deda, & Bhagat, 2015; Lyu, Cao, Wu, Xu, & Xie, 2018; Toroyan & Peden, 2007). Studies focused on ambulance drivers confirmed that the probability of being involved in collisions for such age categories is higher than others (Custalow & Gravitz, 2004; Galazkowski et al., 2015). Noting that the reason behind more involvement in collisions for ambulance drivers aged between 25 and 45 can be due to a higher staff count in this age group.

When an ambulance is involved in a collision while transporting a patient, it rapidly increases the risk of having injuries/deaths compared to other types of collisions, especially when the person being transported is already being taken care of for a particular health condition. To address this, we need to develop comprehensive proactive measures such as training programs designed specifically for less experienced drivers, or provide training on ambulance operators to focus on inadequate skills and abilities or operator errors (Elling et al., 2018; Boone et al., 2015). Use of emerging technology e.g., telematics devices (Levick & Swanson, 2005) can improve driver behavior. To achieve this goal, it's important to enhance the policies and standards for recruiting paramedics. By setting up clear and adaptable standards that consider the specific challenges of ambulance driving, and by integrating focused training and education plans, we can create a proactive strategy within the emergency medical services framework. This combined effort not only tackles the immediate issue of reducing collisions but also demonstrates a dedication to the ongoing safety and welfare of emergency personnel and the communities they serve.

LIMITATION

Exposure variables like the number of emergencies and non-emergency calls or miles driven in different regions, e.g., west and east regions of Montréal, are not available to see the possible reason behind the different distribution of collisions in such times and locations. The distribution of these exposure variables for different ranges of age, experience, and sex or in different weather conditions and activities including emergency and non-emergency are not accessible. In addition, this study is faced with a limitation regarding the number of paramedics with different experiences and age groups.

CONCLUSION

First responders' work-related collisions, especially among paramedics, are a major concern regarding road safety and health and safety. Also, the trend of ambulance collisions is not decreasing in Montréal during the studied period. It is concluded that male and young drivers with low experience (less than seven years) have a history of multiple collisions more than others. In addition, among risky locations, e.g., commercial and residential areas, crossing the intersections with traffic lights can increase the odds of collision severity significantly. Interventions aimed at reducing non-emergency and on-site activities could reduce significantly the odds of being involved in injury collisions compared to emergency calls. These key factors can help paramedicsÕ organizations to focus on target populations like young drivers or those who are involved in multiple collisions in a short timeline. Then, they could tailor either educational content for all or implement specific driving maneuvers programs that have been identified as problematic for their organizations and that have been shown promising in other clientele of drivers to reduce the burden of collisions (Tiesman et al., 2019) or inappropriate visual search as an example (Castellucci et al., 2020).

DATA AVAILABILITY STATEMENT

The data that supports this study's findings are available upon request from the corresponding author, ML. Data are not publicly available, due to ethical and privacy restrictions.

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