Outdoor Falls in an Urban Context: Winter Weather Impacts and Geographical Variations

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ABSTRACT

Objectives: Environmental factors associated with winter outdoor falls are poorly understood. This study describes the demographic, spatial and temporal distribution of outdoor falls that occurred in Laval and Montréal Island (Canada) in relation to meteorological conditions.

Method: Data on falls, including geographic coordinates, were obtained from ambulance services (December 1, 2008 to January 31, 2009). Meteorological (temperature, precipitation levels) and land use data were used for descriptive analysis and mapping.

Results: During the study period, 3,270 falls required ambulance interventions, of which 960 occurred outdoors. Most people injured outdoors were under 65 years of age (59%). Mapping showed a concentration of outdoor falls in central neighbourhoods and on commercial streets in Montréal. Three episodes of excess falls, representing 47% of all outdoor falls, were preceded by rain and followed by falling temperatures, or were concomitant with freezing rain.

Conclusion: Our results demonstrate for the first time the distribution of outdoor falls in a densely populated urban setting with a northern climate. To promote active transportation, it is essential to take into account the safety of pedestrian travel. Snow removal and de-icing operations in municipalities should prioritize areas with high pedestrian activity.

Key words: Accidental falls; injuries; weather; rain; walking

La traduction du résumé se trouve à la fin de l'article.

Can J Public Health 2012;103(3):218-22.

Falls account for approximately 2,300 deaths and 110,170 hospitalizations each year in Canada.[1] Several studies show seasonal variations in rates of falls and fractures of the hip[2-6] and upper limbs,[2,4-6,8] with winter weather conditions such as cold temperatures, snowstorms and ice storms frequently associated with increased rates.[3-6,9-12] Hospital emergency department visits or hospitalizations for fall injury have been shown to peak 4 to 8 days following an ice storm.[12-14] On Montréal Island, the total number of fall-related hospitalizations is about 25% higher during winter, with hip fractures from falls increasing by about 33%.[15] A study among older adults (aged 50+ years) in Montréal showed that freezing rain was the meteorological condition with the greatest risk of hip fracture, although snow and low temperatures also contributed.[3]

To prevent outdoor fall-related injuries, more information regarding the context in which they occurred would be useful. Furthermore, the implementation of environmental preventive strategies requires some knowledge of the spatial distribution of the falls.[16] Most studies cited above do not distinguish between indoor or outdoor falls.[3-5,9,12] Although outdoor falls can be identified with International Classification of Diseases (ICD) codes used in hospital records,[17] in Quebec (Canada) this contextual information is not recorded for a quarter (25%) of all hospitalizations related to falls.[18] Furthermore, while hospitalization registries usually include the place of residence (postal code), there is no information on the location of injury. In addition, unlike for collisions involving motor vehicles, police accident reports are not systematically completed for pedestrian falls on public roadways. Consequently, little is known of the environmental factors associated with outdoor falls, and analysis of their spatial distribution is rare. In Hong Kong, a spatial analysis described the location and environmental factors associated with outdoor falls, but was limited to a small area (2.7 km^2).[19,20] A study of the geographic distribution of road-related injuries in Montréal showed that injury sites can be accurately located using the geographic coordinates recorded in ambulance interventions,[21] making the exploration of environmental features of those sites possible.

The aim of this study is to describe the demographic, spatial and temporal distribution of winter outdoor falls in Laval and on Montréal Island, with particular reference to meteorological conditions.

METHODS

Laval and Montréal Island, located in the Montréal metropolitan area (province of Quebec, Canada), constituted the study area. In

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Acknowledgements: The research was made possible by in-kind support from the Montreal Public Health Department, in particular Louis Drouin, coordinator of Urban Environment and Health sector. We thank Fatna Louali for help in data collection, and Sylvie Gauthier who edited the English version. We express our sincere gratitude to Urgences-santé for their willing collaboration and expertise in injury data collection and validation.

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Conflict of Interest: None to declare.

Figure 1. Study population

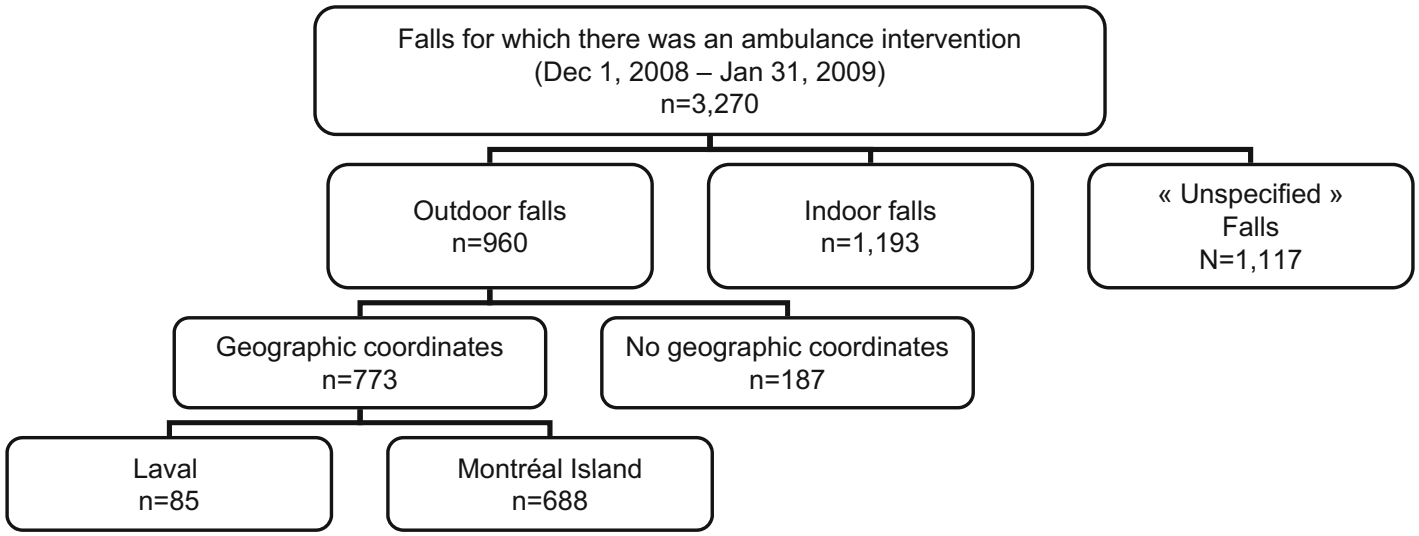
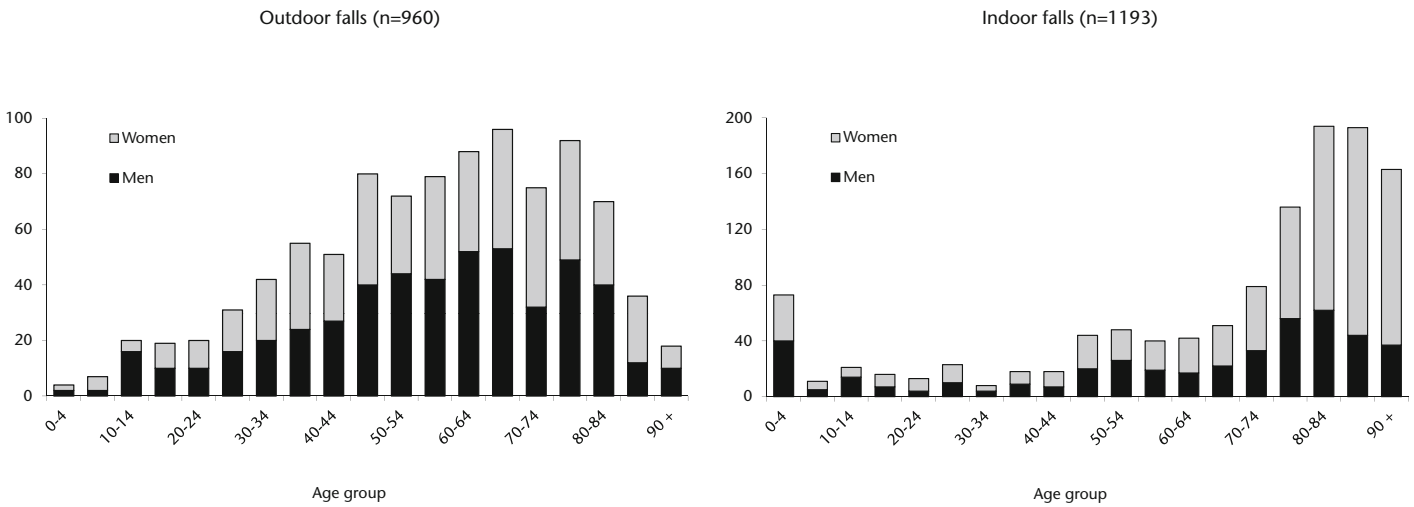


Figure 2. Distribution of individuals injured as a result of an outdoor or indoor fall, by age and sex (Laval and Montréal Island; December 1, 2008 to January 31, 2009)



2006, this 746 km² territory had a population of 2,223,151 people[22] across 16 different municipalities. The study population included individuals injured from a fall sustained between December 1, 2008 and January 31, 2009 in Laval and on Montréal Island, for which there was an ambulance intervention. Falls that occurred on the same level or from a height were included. Intentional falls (i.e., suicide, assault or fight) and falls involving a motor vehicle or bicycle were excluded.

Data and variables

Information on falls was extracted from Urgences-santé Corporation, the only ambulance service in Laval and on Montréal Island. The age and sex of the victim and the date, type of fall (outdoor, indoor, unspecified) and other descriptors of the fall (e.g., ice, snow, "slipped") were retrieved manually from each pre-hospital intervention report completed by ambulance attendants. The geographic coordinates of the injury (longitude, latitude) were obtained from the call register. Since Urgences-santé's regular information systems were not functioning on December 6 and 7, 2008, those two days were excluded.

Meteorological conditions recorded at Montréal's international airport were obtained from Environment Canada's website. Variables included maximum daily temperature (°C), total daily precipitation (rain, in millimetres; snow, in centimetres) and presence of freezing rain.

Analyses and cartography

SPSS 12.0.2 was used for descriptive analyses. Geographic coordinates of outdoor falls were mapped using ArcGIS version 9.1 and their density (per square kilometre) was calculated for Montréal Island. Maps included the Montréal hierarchical road network and Montréal land use.[23]

RESULTS

During the two-month period between December 1, 2008 and January 31, 2009, 3,270 falls required ambulance intervention in Laval and on Montréal Island. Of these, 960 (29%) falls occurred outdoors, 1,193 (36%) indoors, and for 1,117 (34%), the type of fall was not specified (Figure 1).

Figure 3. Geographical distribution of outdoor falls (Laval and Montréal Island; December 1, 2008 to January 31, 2009)

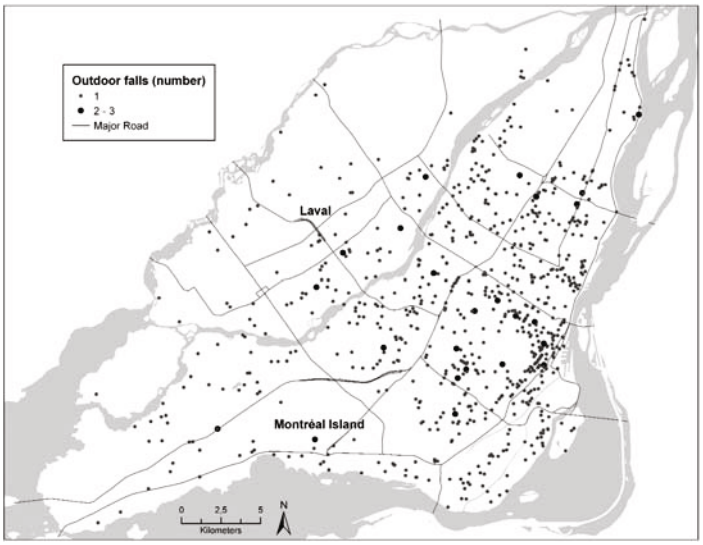
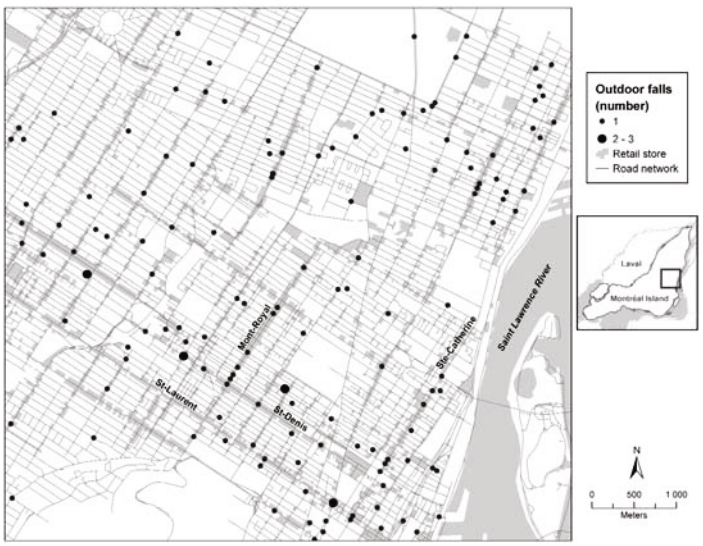


Figure 4. Distribution of outdoor falls and retail store land use in central Montréal neighbourhoods



Demographic distribution

Individuals injured outdoors tended to be younger than those injured indoors (average age 57 vs. 67 years) (Figure 2). Only 6% of people who fell outdoors were aged 85+ years (30% for indoor falls) whereas 59% were aged under 65 years (31% for indoor falls). Similar proportions of males (52%) and females (48%) sustained injuries following an outdoor fall, while a greater proportion of females (63%) than males were injured from indoor falls. The characteristics of individuals injured in "unspecified" falls (average age 64 years; 22% over 85 years; 42% under 65 years; 58% females) resembled those of individuals injured indoors.

Circumstances and spatial distribution

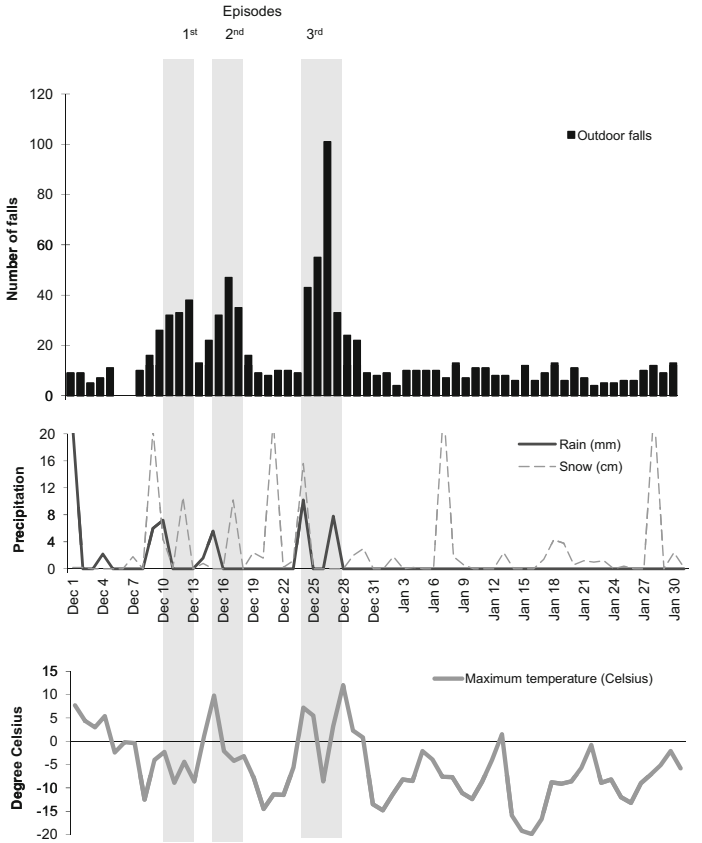
For 688 (72%) of the 960 outdoor falls, the ambulance attendant explicitly stated that the fall was associated with ice (n=580) and/or snow (n=44) and/or "slipping" but with no other information about surface (n=69). Furthermore, for 349 (36%) outdoor falls, ambulance attendants indicated that the fall occurred on sidewalks (n=200), stairs (n=52), roads (n=45), private yards (n=18), skating rinks (n=18) and parking lots (n=16).

Table 1. Number of Outdoor Falls per Square Kilometre on Montréal Island, According to Land Use

Land-use Description	Area km²	Outdoor Falls n	Outdoor Falls n/km²
High-density residential	9.60	63	6.56
Retail store	23.15	138	5.96
Office building	3.52	18	5.11
Shopping centre	5.54	16	2.89
Medium-density residential	70.17	200	2.85
Community facilities	31.97	45	1.41
Low-density residential	111.00	90	0.81
Public utilities	40.72	29	0.71
Green space	46.85	33	0.70
Industrial	61.93	24	0.39
Other*	84.80	32	0.38
Montréal Island	489.25	688	1.41

Outdoor falls in Laval were not included.
* Other: Golf, cemetery, vacant land, etc.

Figure 5. Outdoor falls and meteorological conditions: Daily data (Laval and Montréal Island; December 1, 2008 to January 31, 2009)



Geographic coordinates were available for 773 (81%) outdoor falls – 85 in Laval and 688 on Montréal Island. Mapping showed a concentration of outdoor falls in central neighbourhoods (Figure 3), especially on commercial streets (Figure 4). On Montréal Island, most outdoor falls occurred in residential and retail store areas (Table 1). The number of outdoor falls per square kilometre was highest in high-density residential, retail store and office building areas.

Temporal distribution

On average, 16 outdoor falls per day required ambulance intervention in Laval and on Montréal Island during the study period.

The daily distribution of outdoor falls shows that in December, there were three episodes where the daily number of falls was at least twice this average: December 11-13; 16-18; and 25-28 (Figure 5). In all, there were 449 outdoor falls over these 10 days, representing 47% of the total number of outdoor falls observed during the 60-day period.

Daily meteorological data were associated with outdoor falls for the study period (Figure 5). During the first episode of excess falls (December 11-13), there were below-zero temperatures, snowfalls on December 9 to 12 inclusively and freezing rain on December 9 and 10. The second episode (December 16-18) also had below-zero temperatures, snowfalls on December 14 and 17 and rain on December 14 and 15. The third episode (December 25-28) had temperatures above zero (except December 26), snow and freezing rain on December 24 and freezing rain on December 27.

All three episodes of excess falls were preceded by rain and followed by falling temperatures, or had freezing rain. Moreover, we observe that the largest increase in outdoor falls occurred 1 to 3 days after meteorological events favourable to the formation of ice on sidewalks (e.g., rain followed by falling temperatures). In January, when temperatures were cold and constantly below 0°C and there was snow but no rain, no excess cases of falls were observed.

DISCUSSION

The current study describes the demographic, spatial and temporal distribution of outdoor falls in relation to meteorological conditions for two large urban centres in Canada. In contrast to indoor fall injuries that mostly occurred among elderly individuals, most people injured outdoors were under 65 years of age (59%). Another Montréal study among older adults previously found that inclement weather conditions were more strongly associated with fall-related hip fractures for those aged 50-64 years than for those 65+ years.[3] Lower numbers of outdoor falls among the elderly may reflect a reduction of outdoor activities among older people, especially during winter.

To our knowledge, no study has examined the geographical distribution of outdoor falls in an extensive urban area. The Hong Kong study was limited to a small high-density area and, as cases were recruited from a single hospital, it was not population-based.[19,20] A Montréal study, published in 2002, used ambulance data to obtain the number of outdoor falls, but it was limited to individuals aged 55+ years and did not include geographical locations.[2] We found that outdoor falls were concentrated in central neighbourhoods. This may be due in part to a higher likelihood of calls for ambulances in these areas. However, the greater density of outdoor falls in high-density residential, commercial and office areas likely corresponds to the distribution of pedestrians in Montréal, since these land-use characteristics are associated with higher pedestrian activity and, thus, more people exposed to potential falls. Density and mixture of urban functions are known to influence walking patterns.[24,25] The proportion of households not owning a car is much higher on Montréal Island (33%), especially in the central boroughs (from 31% to 53%), than in Laval (11%).[26] In addition, many other unmeasured environmental factors could affect the observed incidence and distribution of outdoor falls (e.g., road geometry, presence or condition of sidewalks, and quality of snow removal and de-icing).

In our study, almost half (47%) of outdoor falls observed over a 60-day period occurred on 10 days spread over three episodes. Serious injury following outdoor falls in winter appears to be highly influenced by the number and duration of episodes of freezing rain, or rain followed by a drop in temperature. Ours is the first study to clearly distinguish outdoor and indoor falls and to show that rain followed by a drop in temperature may also be an important meteorological factor for outdoor falls.

Pedestrians are vulnerable road users. In Canadian cities, in addition to the well-known risk of being injured in a motor vehicle collision,[21,27] pedestrians also experience some risk of fall-related injury in winter. Prevention strategies are clearly needed. In the last 60 years, pedestrians were typically given minimal consideration in the design of roadway systems. The movement of motorized vehicles tends to remain the primary objective for road engineers and snow and ice clearance efforts. Yet pedestrians should be recognized as important parts of the transportation system, especially in current times of increasing obesity and climate change concerns when public health campaigns promote active modes of transport. In large cities like Montréal, walking is not only the most common physical activity for young people and adults, it is also an essential component of urban mobility. From a public health perspective, it is essential that efforts to promote active transportation take into account the safety of pedestrian travel.

Snow removal and sanding operations in municipalities should take into account pedestrian safety and prioritize areas with high pedestrian traffic, central neighbourhoods, commercial arteries and areas close to public transport routes. This issue also concerns private owners of outdoor stairs and parking lots.

Limitations

Urgences-santé's information systems allowed rapid identification, using few resources, of a large number of outdoor falls that occurred during December 2008 and January 2009 in Laval and on Montréal Island. However, as ambulance interventions are only the tip of the iceberg, including only the most severe injuries, this study underestimates the total number of outdoor falls. In addition, the detailed information written by ambulance attendants for each fall does not always allow identification of outdoor falls. However, only a minority of "unspecified" falls were likely to be outdoor falls since their distribution by day, age and sex is relatively similar to that observed for indoor falls. To obtain more information on fall circumstances, and reduce the proportion of "unspecified" falls, future research could include interviews with injured people.

This study only included descriptive spatial analysis. Selection bias cannot explain the observed geographical distribution since Urgences-santé is reached through 911 calls and has a monopoly over ambulance services in the territory studied. In addition, universal health care directly pays hospitalization fees. It was impossible to obtain geographic coordinates for 19% of outdoor falls because this exploratory study was based on a manual review of each ambulance intervention report; this figure would undoubtedly be lower in a retrospective study using the regular information system, as shown for injured pedestrians.[21] Land-use data were only available for Montréal Island.

CONCLUSION

Our results demonstrate for the first time the extent and geographical distribution of severe outdoor falls in a densely populated urban setting with a northern climate. Winter outdoor falls

appear to be highly influenced by the number and duration of episodes of freezing rain, or rain followed by a drop in temperature.

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Received: January 16, 2012
Accepted: March 31, 2012

RÉSUMÉ

Objectifs : Les facteurs environnementaux liés aux chutes extérieures en hiver sont méconnus. Cette étude décrit l'ampleur et la localisation des chutes extérieures survenues à Montréal et à Laval (Canada), ainsi que les conditions météorologiques associées.

Méthodologie : Les caractéristiques des chutes extérieures, incluant la localisation géographique, proviennent des interventions ambulancières (1er décembre 2008 au 31 janvier 2009). L'analyse descriptive inclut les données météorologiques (température, précipitations) et l'occupation du territoire.

Résultats : En deux mois, 3 270 chutes ont nécessité une intervention ambulancière, dont 960 chutes extérieures. La majorité (59 %) des personnes blessées à l'extérieur ont moins de 65 ans. La cartographie montre une concentration des chutes extérieures dans les quartiers centraux montréalais et sur les rues commerciales. Trois épisodes d'excès de chutes, qui représentent 47 % des chutes extérieures, sont associées à la pluie suivie d'un refroidissement ou au verglas.

Conclusion : Ces résultats démontrent l'étendue et la localisation du problème des chutes extérieures dans un milieu urbain densément peuplé, soumis au climat nordique. La promotion des transports actifs implique une prise en compte de la sécurité des déplacements à pied. Dans les municipalités, les opérations de déneigement et d'épandage d'abrasif devraient prioriser les zones de forte affluence piétonne.

Mots clés : chutes; blessures; climat; marche