Daily number of fractures is associated with road temperature in an urban area

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ABSTRACT

INTRODUCTION: Different factors related to winter are known to influence the fracture incidence, but little is known about the effect of road surface temperature. This study examines the association between road surface temperature and the daily number of fractures in an urban area during two winters.

MATERIAL AND METHODS: Retrospective data collection was conducted on all patients treated at Bispebjerg Hospital, Denmark, for a humeral, ankle, distal radius or hip fracture during the periods October to April 2009/2010 and 2010/2011. Patients were grouped according to age into the following categories: < 15, 15-30, 30-45, 45-60 and > 60 years. Data on road surface temperature (Tp.) were obtained from The Danish Road Directorate and grouped into the following categories: Days with Tp. > 0 °C, Tp. < 0 °C, Tp. > –5 °C, Tp. < –5 °C and ice alert (IA).

RESULTS: A total of 4,892 patients (4,938 fractures) were treated during the study periods. The daily number of distal radius, humeral and ankle fractures increased significantly with decreasing road surface temperature and the presence of IA. For hip fractures no significant association was found. Decreasing temperature was associated with a significant decrease in the daily number of fractures for patients < 15 years, whereas patients > 30 years experienced a significant increase.

CONCLUSION: Decreasing road temperature results in increased numbers of all fractures except hip fractures. Low temperatures is a risk factor for patients > 30 years and a protective factor for patients < 15 years.

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Seasonal variation influences the incidence of fractures, which are more common during winter than during summer [1-4]. The seasonality is evident for different types of fractures including fractures of the ankle, arm and forearm [4, 5], whereas the literature on hip fractures is inconsistent with some [1-3], but not all [6-8] studies reporting seasonal variation. Different environmental factors associated with winter may explain this seasonal increase. As such, an increased incidence is found on days with adverse weather and with the presence of wintery road conditions [1, 4, 9-11]. Another component of seasonality could be the lower ambient temperature during winter, but the literature is inconclusive with some authors reporting a correlation between temperatures and incidences [1, 3], whereas others do not [6, 12]. Whereas many studies have explored the effect of seasonality, weather, road conditions and ambient temperature on fracture incidence, little is known about the association with road surface temperature. The purpose of this study was to examine the association between road surface temperature and the daily number of fractures treated in a trauma unit in an urban area for a period of two winters.

MATERIAL AND METHODS

Patients

Bispebjerg Hospital, Denmark, has a busy trauma unit with a catchment population of approximately 400,000. We retrospectively collected data on all patients treated for a musculoskeletal lesion in our trauma unit during the two winter periods from October to April 2009/2010 and 2010/2011. The data included age, gender and lesion-type. Head injuries and spine injuries together with multi-trauma patients are either admitted to other sections of the hospital or redirected to other trauma units and are therefore not included in this study. The included patients were divided into fractures and other lesions, with the latter being excluded. Fractures were divided into the following subgroups: humeral, ankle, distal radius and hip fractures. Patients were furthermore grouped according to age into the following age groups: < 15, 15-30, 30-45, 45-60 and > 60 years.

Road condition data

Data on road surface temperature (Tp.) in the catchment area during the two periods were obtained from The Danish Road Directorate. Data were grouped into the following categories: Days with Tp. > 0 °C, Tp. < 0 °C, Tp. > –5 °C, Tp. < –5 °C and ice alert (IA), the latter being triggered by a combination of low temperature and the presence of high humidity. For the purpose of analysis, the temperatures of a given day were grouped according to one of the above-mentioned categories if at any time during the day, it dropped below the limit of that category. A more detailed description of the data can be obtained from the authors. The Danish Road Directorate collects data through a number of measuring stations

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Decreasing road temperatures and ice alert are associated with increased numbers of fractures in urban areas.

spread around the catchment area. These register the road- and ambient temperature together with the humidity on a five-minute basis, and it is therefore possible to continuously monitor the temperature and the humidity of the surface of the roads. Registration of road surface temperature is conducted by a temperature sensor usually placed in the wheel track at one of the driving lanes. The sensor is placed in a small hole with the sensor top located at par with the road surface. The sensor is connected to the measurement station by the roadside by wires milled a few centimetres into the pavement.

Statistical analysis

The number of fractures per day was not normally distributed. To test for differences in the daily number of fractures as a function of road conditions, non-parametric methods were therefore used (Mann-Whitney U tests) with a p-value < 0.05 considered statistically significant. The same test was used for calculating the association between road temperature and the daily number of fractures in the different age groups.

The study was approved by the Danish Data Protection Agency.

Trial registration: not relevant.

RESULTS

A total of 4,892 patients who had suffered a total of 4,938 fractures were treated during the two periods (**Table 1**). The daily number of humeral, ankle and distal radius fractures varied significantly with road surface temperature, whereas hip fractures were unaffected (**Table 2**). Age was also found to influence the daily number of fractures with decreasing road temperatures being significantly associated with an increase in fractures among patients > 30 years of age (**Table 3**). For patients < 15 years of age, an inverse pattern was seen with a significant decrease at Tp. < 0 °C and a non-significant decrease at Tp. < –5 °C. On days with IA, the number of fractures was found to increase significantly for patients > 30 years, whereas it decreased insignificantly for patients < 30 years.

DISCUSSION

In our study, we found that decreasing road temperature and the presence of IA was associated with an increase in the daily number of all fracture types except hip fractures. It has previously been shown that the incidence of fractures varies with the season, with greater occurrences of fractures during winter [1-4]. This may be explained by different conditions related to this time of the year. As such, cold, inclement, snowy and icy weather, low ambient temperature and snowy/icy roads are all associated with an increased fracture incidence [1, 4, 9-11], indicating that the aetiology of the winter excess is multi-factorial. We found that decreasing road temperatures were associated with an increase in daily number of ankle, distal radius and humeral fractures, but not hip fractures. Similarly, other studies have shown no influence of season [5, 6], ambient temperature [6, 12] and weather conditions [9] on the occurrence of hip fractures. This lacking correlation may be due to the fact that hip fractures more frequently occur indoors [13], consequently the incidence is consequently less affected by outdoor conditions. Supporting the importance of outdoor factors, Bergstrom et al [14] reported seasonal variation for hip fractures occurring indoor but not outdoor, and Oyen et al [15] showed a lack of seasonality for distal radius fractures occurring indoors. Likewise, distal radius fractures are more frequent among active individuals who are more likely to be outdoors [11]. Overall, this indicates that outdoor conditions contribute to the increased risk during winter. In line with this, we found that the number of all fracture types, except hip fractures, increased significantly on days with IA. This indicates that under-foot conditions, such as slippery pavement, can affect the risk of incurring such fractures. Other studies have also shown that snowy/icy road and weather conditions increase the risk of fracture [9, 10]. While slipping seems an obvious and simple reason for the increased incidence during winter, not all agree on this. Jacobsen et al [2] suggested that other variables than under-foot conditions are responsible for the excess incidence during winter. In support of this, Douglas et al [16] found seasonal variation for hip fractures in both Scotland, Hong Kong and New Zealand even though Hong Kong is without snow and ice during the winter season. Other suggested aetiological mechanisms include: 1. Hypothermia and undernutrition [17]; 2. Impaired bone quality during winter [18]; 3. Decreased muscle strength due to vitamin-D deficiency [19].

Regarding age, we found that patients in the groups > 30 years experienced a significant increase in the daily number of fractures at lower temperatures and with the presence of IA. For patients 15-30 years of age, decreasing road surface temperature and IA were insignificantly associated with a decrease in the number of fractures. In the group < 15 years, an inverse pattern was detected with a significant decrease in the number of fractures when comparing days with Tp. > 0 °C and < 0 °C. When comparing days with Tp. > –5 °C and < –5 °C, an insignificant decrease were found and this was also evident on days with IA. This inverse pattern for patients < 15 years has earlier been shown for distal radius fractures [20]. In this study, higher rates of fractures were found during summer than during winter, a possible explanation being better weather enc+ouraging outdoor activities and thus an increased risk of accidents and fractures. As such, decreasing road temperatures during winter seems to be a risk factor for patients > 30 years and a protective factor for patients < 15 years, whereas IA is only a risk factor for patients > 30 years. It is important to remember that we only looked at the daily number of fractures in the different age groups and did not take into account the population at risk.

Due to this, direct comparison between the different groups is not possible and the results only serve to show whether decreasing road surface temperature and IA are associated with an increase in the daily number of fractures in the groups.

Limitations of our study include the retrospective data collection. Also, fractures occurring indoors are not excluded since it is not possible with the available data to differentiate between these and fractures occurring outdoors. Furthermore, since we examined an urban population, our results cannot be applied to the general population. There is also a small possibility that patients suffering a fracture in our catchment area are admitted to other hospitals, in which case the number of fractures would have been underestimated. Regarding data on road surface temperature, days were grouped according to the lowest temperature registered at any time during the day and not the mean temperature, and this could also result in an underestimation of the effect of the temperature. The most important strengths of this study are the large number of consecutive patients included ++together with the method and precision by which data were collected.

TABLE 1

Basic characteristics.

Patients, n	
< 15 yrs	581
15-30 yrs	856
30-45 yrs	716
45-60 yrs	822
> 60 yrs	1,917
Total (men:women)	4,892 (2,161:2,731)
Age, yrs, mean (± SD)	49.9 (± 26.5)
Fractures, n	
Humerus fractures	442
Distal radius fractures	767
Hip fractures	628
Malleolus fractures	347
Total	4,938
Days with road condition , n	
Tp. > 0 °C	193
Tp. < 0 °C	231
Tp. > –5 °C	318
Tp. < –5 °C	106
Ice alert	79
Total	424
Fractures per day, n, mean (± SD)	11.6 (± 5.5)

SD = standard deviation; Tp. = road surface temperature.

TABLE 2

Number of fractures per day at registered road temperatures.

	Road condition		
	> 0 °C[a] vs < 0 °C[a]	**> ⍰5 °C[a] vs < ⍰5 °C[a]**	**⍰IA vs +IA**
Days, n	193 vs 231	318 vs 106	345 vs 79
Humeral fractures			
n	170 vs 272	298 vs 144	332 vs 110
n/day, median (min.-max.)	1 (0-5) vs 1 (0-8)	1 (0-5) vs 1 (0-8)	1 (0-5) vs 1 (0-8)
p-value	0.007	0.001	0.007
Ankle fractures			
n	109 vs 238	207 vs 140	229 vs 118
n/day, median (min.-max.)	0 (0-3) vs 1 (0-12)	0 (0-6) vs 1 (0-12)	0 (0-6) vs 1 (0-12)
p-value	0.002	0.0003	0.0002
Distal radius fractures			
n	282 vs 485	495 vs 272	573 vs 194
n/day, median (min.-max.)	1 (0-6) vs 2 (0-12)	1 (0-8) vs 2 (0-12)	1 (0-12) vs 2 (0-8)
p-value	0.004	0.0001	0.002
Hip fractures			
n	260 vs 368	467 vs 161	481 vs 147
n/day, median (min.-max.)	1 (0-6) vs 1 (0-14)	1 (0-8) vs 1 (0-14)	1 (0-6) vs 2 (0-14)
p-value	0.2	0.9	0.1

IA = ice alert.
a) Road surface temperature.

CONCLUSION

The aetiology of the excess fracture incidence during winter is multi-factorial. The present study highlights the effect of road surface temperature. Decreasing tempera-

TABLE 3

Total number of fractures per day at registered road temperatures in the different age groups.

	Road condition		
	> 0 °C[a] vs < 0 °C[a]	**> ⍰5 °C[a] vs < ⍰5 °C[a]**	**⍰IA vs + IA**
Days, n	193 vs 231	318 vs 106	345 vs 79
Age > 60 yrs			
Fractures, n	746 vs 1,171	1,298 vs 619	1,425 vs 492
Fractures/day, n, median (min.-max.)	4 (0-12) vs 4 (0-24)	4 (0-14) vs 5 (0-24)	4 (0-18) vs 5 (0-24)
p-value	0.001	< 0.0001	< 0.0001
Age 45-60 yrs			
Fractures, n	287 vs 535	549 vs 273	593 vs 229
Fractures/day, n, median (min.-max.)	1 (0-6) vs 2 (0-16)	2 (0-16) vs 2 (0-10)	2 (0-10) vs 2 (0-16)
p-value	0.0004	0.0006	0.0004
Age 30-45 yrs			
Fractures, n	270 vs 446	474 vs 242	531 vs 185
Fractures/day, n, median (min.-max.)	1 (0-5) vs 2 (0-12)	1 (0-6) vs 2 (0-12)	1 (0-10) vs 2 (0-12)
p-value	0.01	0.002	0.02
Age 15-30 yrs			
Fractures, n	359 vs 497	608 vs 248	701 vs 155
Fractures/day, n, median (min.-max.)	2 (0-7) vs 2 (0-10)	2 (0-7) vs 2 (0-10)	2 (0-10) vs 2 (0-6)
p-value	0.1	0.06	0.9
Age < 15 yrs			
Fractures, n	306 vs 275	449 vs 132	484 vs 97
Fractures/day, n, median (min.-max.)	1 (0-7) vs 1 (0-8)	1 (0-8) vs 1 (0-8)	1 (0-7) vs 1 (0-8)
p-value	0.002	0.2	0.1

IA = ice alert.
a) Road surface temperature.

ture and the presence of IA is associated with an increased number of all fracture types except hip fractures. Decreasing road temperature seems to be a risk factor for patients > 30 years of age and a protective factor for patients < 15 years of age, whereas IA is only a risk factor for patients > 30 years. These results may have implications for the prevention of accidents and the planning of staff in trauma units and orthopaedic wards. Since this is the first study examining the effect of road temperature, larger prospective studies are needed to confirm these findings.

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