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ORIGINAL PAPER

Orthopaedic patients' emergency department attendance behavior in relation to weather conditions: temperature, rain, day and time, and regional thursday effect

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Abstract

Great variation was noticed in emergency department (ED) afflux in relation to daily weather conditions, including difficulties in arranging the correct number of orthopaedic on-calls on the floor. This study aimed to quantify the association between the number of patients referred to the orthopaedic team from the ED and weather conditions, particularly daily temperature and rain. Data were obtained from a large state research hospital's ED attendance. Weather information for the local area for the year was obtained from the regional meteorological office. Data were evaluated using descriptive statistics, with one-way analysis of variance for the relationship between the day of the week and patient numbers, the Pearson test for correlations between daily ED patient flow and daily temperature and the Spearman correlation test for correlations between daily patient flow and daily rain status. A positive and meaningful correlation existed between daily patient influx and daily temperature, along with a negative correlation between daily patient flow and daily rain. Throughout the year, significantly more patients were referred to the orthopaedic team on Thursdays than on any other day of the week. Patients tended to visit the ED more on warm days and days without rain. These results may help in organising daily, monthly or seasonal on-call orthopaedic team requirements despite the challenges. Incorporating climate forecasts into planning the on-call service might help alleviate the stress on the team.

Introduction

Hospital attendance can be linked to variations in the weather. Seasonal variations can also exist. Although respiratory complaints and related visits increase in winter, skin problems, allergic presentations and digestive diseases are more common in summertime (Macgregor 2003; Lee et al. 2016). This may affect the number of admissions to hospitals. Previous reports have shown such relationships between weather conditions and hospital attendance and admissions (Macgregor 2003; Lee et al. 2016; Ramgopal et al. 2019; Ou et al. 2005). Increased outdoor activities on warm and sunny days may lead to traumatic injuries in paediatric populations (Parsons et al. 2011). Similarly, poor weather conditions such as heavy rain may cause more road accidents and thus more hospital arrivals (Parsons et al. 2011). However, patients are believed to be less likely to visit hospitals in poor weather conditions (Lee et al. 2016).

Emergency visits are free in all state hospitals in our country, and the orthopaedic department deals with many patients in the ED, including orthopaedic referrals. Variation has been noticed in patient flow in relation to daily weather conditions, as well as difficulties in arranging orthopaedic on-calls on the floor. Only few relevant studies exist in the literature. Therefore, the current study aims to quantify the association between the number of patients referred to the orthopaedic team from the ED and weather conditions, particularly the daily temperature and amount of rain.

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Table 1 Daily average number of patients consulted with orthopaedics for each month, according to eight-hourly period, mean daily temperature and amount of daily rain

Month	Mean number of patients ± SD/day	Mean number of patients ± SD between 00:00 and 08:00	Mean number of patients ± SD between 08:00 and 16:00	Mean number of patients ± SD between 16:00 and 24:00	Mean daily temperature (ºC)	Mean daily rain (m^3/m^2)
January	20.35 ± 4.05	2.48 ± 1.75	7.16 ± 2.38	10.71 ± 2.84	7.65 ± 3.1	1.57 ± 2.59
February	27.25 ± 6.56	2.07 ± 1.51	11.21 ± 4.45	13.96 ± 4.73	8.99 ± 3.2	1.69 ± 2.93
March	30.52 ± 8.54	2.74 ± 1.81	12.45 ± 4.58	15.32 ± 6.15	12.31 ± 4.05	3.47 ± 4.21
April	42.87 ± 10.58	3.07 ± 1.93	19.93 ± 7.31	19.87 ± 5.65	15.43 ± 2.93	0.63 ± 1.44
May	37.81 ± 9.57	3.13 ± 2.36	18.19 ± 7.56	16.84 ± 5.69	19.09 ± 3.01	4.43 ± 8.4
June	36 ± 7.79	4.37 ± 2.44	13.67 ± 4.94	17.97 ± 5.68	23.13 ± 1.75	1.69 ± 3.39
July	45.42 ± 9.45	5.19 ± 2.46	18.03 ± 4.96	22.23 ± 8.77	24.93 ± 0.99	3.19 ± 6.67
August	48.57 ± 8.94	5.16 ± 3	19.1 ± 5.73	24.16 ± 6.55	25.71 ± 1.07	0.37 ± 1.28
September	35.77 ± 9.49	3.53 ± 2.19	14.7 ± 5.68	17.53 ± 6.11	21.17 ± 2.7	1.67 ± 2.56
October	36.52 ± 9.83	2.39 ± 1.63	16.39 ± 7.68	18.06 ± 5.24	17.49 ± 2.33	1.86 ± 4.32
November	35.03 ± 11.94	2.47 ± 2.06	15.47 ± 7.89	17.5 ± 6.51	12.86 ± 3.01	2.43 ± 3.99
December	30.87 ± 9.12	2.65 ± 1.56	13.42 ± 6.07	14.84 ± 5.24	7.36 ± 2.97	5.03 ± 5.31

SD: standard deviation

Table 2 Correlation between daily patient numbers, daily temperature and daily rain for four seasons

Season	Mean number of patients ± SD/day	Correlation between daily patient numbers and daily temperature (Pearson)	Correlation between daily patient numbers and daily rain status (Spearman)
Winter	26.12 ± 8.15	R = -0.092, $p = 0.383$	r = 0.146, $p = 0.17$
Spring	37 ± 10.76	R = 0.3, $p = 0.0037$	r = -0.337, $p = 0.001$
Summer	43.34 ± 10.12	R = 0.43, $p = 0.00002$	r = -0.26, $p = 0.014$
Autumn	35.78 ± 10.37	R = 0.15, $p = 0.17$	r = -0.04, $p = 0.73$

SD: standard deviation

Materials and methods

This was a retrospective study. The data were obtained from a large state research hospital's emergency attendance record related to daily and eight-hourly numbers of patients consulted by the orthopaedic team. The involved hospital is a tertiary centre, affiliated with a university, having a catchment area of over one million; this is the main hospital in the region with full ED facilities and on-call orthopaedic physicians after 5 pm, weekends and holidays. Nearby hospitals do not have onsite orthopaedic on-call systems.

Although the reasons for orthopaedic referral varied, records involved mostly trauma patients, fractures, other musculoskeletal injuries and infections. The methodology of the study did not categorise the reasons for orthopaedic consultations.

Weather information for the local area for all 365 days of the year 2018 was obtained from the meteorological office for a city in the northwest of Turkiye (Sakarya). The data were converted into an Excel sheet and evaluated using descriptive statistics: one-way analysis of variance (ANOVA) for the relationships between the day of the week and patient numbers, the Pearson test for correlations between daily patient numbers and daily temperature and the Spearman correlation test for correlations between daily patient numbers and daily rain status. An amount of rain equal to or over 1 m^3/m^2 was considered a positive rain status for that day. $P < 0.05$ was considered statistically significant.

Results

Table 1 shows that fewer patients presented overnight. Although the mean numbers of patients between 08:00 and 16:00 and between 16:00 and 24:00 were similar, the numbers were generally higher between 16:00 and 24:00, which could be considered out-of-hours. More daily rain was seen in December, May and March (in decreasing order).

More patients attended in August and July, followed by April and May; the mean amount of rain was the least in August and April. More patients tended to present in summer months and warmer weather, whereas their numbers were lower in winter months (Table 1).

A positive and meaningful correlation existed between daily patient numbers and daily temperature, especially in spring and summer (Table 2). A meaningful and negative correlation was found between daily patient numbers and daily rain status (Table 2). Therefore, as the temperature

increased, the daily number of patients who attended the emergency department and consulted with the orthopaedic team increased, and as the amount of daily rain increased, the number of patients decreased, especially in spring and summer.

When taking the whole-year correlations into account between daily patient numbers, daily temperature and daily rain, a positive and meaningful correlation existed between daily patient numbers and daily temperature ($R = 0.57$, $p < 0.0001$), with a negative correlation between daily patient numbers and daily rain status ($r = -0.216$, $p = 0.00017$).

When considering the day of the week and the number of patients referred to orthopaedics for a whole year using one-way ANOVA, statistically significant differences existed between Saturday and Tuesday, between Thursday and Tuesday, and between Thursday and Wednesday. The *f*-ratio value was 5.22626. The *p*-value was 0.000462. The result was significant at $p < 0.05$ (between Thursday and Tuesday: $p = 0.00045$; between Thursday and Wednesday: $p = 0.01680$; between Saturday and Tuesday: $p = 0.01841$).

The daily mean patient numbers referred to the orthopaedic team increased in the summer months but with no statistical difference between the days of the week. The *f*-ratio value was 1.77599. The *p*-value was 0.145256. The result was *not* significant at $p < 0.05$. Interestingly, more patients were referred to the orthopaedic team on average on Thursdays both in the summertime and over the whole year (Table 3).

Discussion

This was a retrospective study to evaluate the relationship between weather conditions and referrals to the orthopaedic team by the emergency department at a large, busy teaching hospital, using whole-year data. It showed a negative correlation between patient numbers and the daily amount of rain and a positive correlation between patient numbers and high daily temperatures. Few such studies exist in the literature, and the available ones have studied different aspects of the issue.

A large study by Parsons et al. (2011) demonstrated a clear association between weather conditions and seasonal increases in paediatric trauma admissions. On the other hand, adult trauma admissions in the UK did not show a similar increase during the summer months (Parsons et al. 2011). The average temperature in the UK during summertime in 2018 was (15.9, 18.7, 16.7) 17.1 ºC (Salas 2023). In our study, the average temperature was 24.59 ºC in the local area in the same year.

Lee et al. (2016) showed an increase in the volume of visits for every 1 °C increase in the diurnal temperature range. When Lin et al. (2015) examined the effect of weather and time on trauma events, their results showed that an hour of sunshine exposure was associated with an increase in the hourly incidence of all groups, and higher temperatures were associated with an increased hourly incidence of total trauma, traffic accidents, and motorbike accidents but not falls. Another study by Robertson et al. (2022) showed a positive relationship between increased temperature and distal radius fracture, which is generally the result of a fall onto an outstretched hand.

Several studies have shown a decreased volume of visits to emergency departments in rainy or cold weather conditions. Lee et al. showed a decrease in the volume of emergency department visits on days with rain or snow, but visits increased two days after poor weather (Lee et al. 2016). According to Lin et al., the hourly incidence of falls increased in late autumn and winter (Lin et al. 2015).

Adverse and extreme weather conditions may also affect patient attendance and orthopaedic referrals, mainly for trauma (Robertson et al. 2022). A study by Yeung et al. (2020) showed that night-freezing events correlated with elevated fall-injury volumes. Similarly, snow days may increase orthopaedic referrals with increased distal radius and ankle fractures, but the same study showed no increase in femur-neck fractures (Weston-Simons et al. 2012).

An important aspect of this study was drawing attention to the variation in patient numbers and thus workload stress on the on-call orthopaedic team with unpredictable patient attendance. All studies including the current one show a clear relationship between weather conditions and emergency department attendance and referrals to orthopaedics. A systematic review by Ali et al. on the effect of the weather on workload concluded that weather conditions may substantially affect trauma workload, independent of the effects of seasonal variation (Ali and Willett 2015). Eventually, the relationship between weather and patient numbers will

Table 3 Daily numbers of patients referred to orthopaedic team from emergency department according to day of week

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Whole year mean patients ± SD/day	35.85 ± 10.82	30.88 ± 11.15	33.31 ± 11.84	40.19 ± 13.26	36.67 ± 11.57	37.9 ± 10.67	34.46 ± 10.02
Summer mean patients ± SD/day	41.08 ± 9.9	36.85 ± 7.07	36.62 ± 13.32	46.15 ± 12.01	39.57 ± 9.33	39.62 ± 4.61	38.62 ± 8.59

SD: standard deviation

place strain on services. Countries with four-hour standard waiting times could have difficulties in achieving this (Hotz and Hajat 2020).

In this study, in all months except May, the volumes of hospital emergency referrals to the orthopaedic team after 16:00 (between 16:00 and 00:00) were higher than during the rest of the day. This could be for two main reasons: normal outpatient departments were closed after 16:00 or patients attended after they finished their daytime work (or both). Another reason could be partly due to being only hospital with full ED facilities in the region. Somehow, more patients attended on Thursdays than on other days, including the weekend, with fewer patients on Tuesdays. Considering the whole year, statistically significant differences existed between Thursday and Tuesday, between Thursday and Wednesday, and between Saturday and Tuesday. Understanding why more patients attended on Thursdays might be difficult. One reason could be that they wanted to be seen before the weekend. Aterthon et al. (2005) did not find the day (school day or school holiday) to be important in paediatric admissions. A study by Sun et al. (2009) showed that ambulant and minor emergency patients had higher attendance on Sundays, with more ill patients with severe symptoms on Mondays. Another study by O'Keeffe et al. (2018) showed more non-urgent emergency department attendances over weekends, with Mondays and Thursdays showing lower attendance. In England in 2021–2022, the most accident and emergency attendances were on Mondays (3.6 million), with the lowest on Saturdays (2.9 million), and Thursdays in the middle (3.3 million; Michas 2023). None of the other studies showed similar pattern on Thursdays with higher patient flow.

An increasing proportion of emergency departments are reporting inadequate numbers of on-call specialists. This might cause a crisis in emergency department on-call coverage for patients requiring orthopaedic care (Agnew et al. 2012). As Ou et al. (2005) suggested, if meteorological forecasting can be incorporated into emergency medicine working schedules, this might improve effective working and alleviate on-call service stress. Although this would be difficult to arrange daily, it could be adjusted monthly, seasonally or according to the day of the week in light of this or similar studies.

Limitation

This study aimed only to assess the number of orthopaedic patients attending the ED in relation to the weather conditions. It did not include any data related to the admissions of the causes nor to whether the patients were adult or paediatric. The available data did not allow us to stratify attendance with respect to "acute onset" or "traumatic" pathologies versus "improper" access to the ED for chronic conditions. Future studies could benefit from subcategorisation of the data by cause (such as trauma, infection or other orthopaedic problems) and age group (adult or child).

Conclusions

A clear relationship exists between patients coming to an ED, the number of patients seen by the orthopaedic team and weather conditions and their seasonal variations. Patients tend to visit the hospital more on warm days, on days without rain and on Thursdays. These results may help in organising daily, monthly or seasonal on-call orthopaedic team requirements. Incorporating climate estimation into on-call service planning might help alleviate team stress.

Data availability The data generated or analysed during this study are included in this published article and available from corresponding author upon reasonable request.

References

Agnew SG, Blotter RH, Kosmatka PK, Rudin GJ (2012) Real-world solutions for orthopaedic on-call problems. Instr Course Lect 61:595–605 PMID: 22301265

Ali AM, Willett K (2015) What is the effect of the weather on trauma workload? A systematic review of the literature. Injury 46(6):945–953. https://doi.org/10.1016/j.injury.2015.03.016

Atherton WG, Harper WM, Abrams KR (2005) A year's trauma admissions and the effect of the weather. Injury 36:40–46

Hotz IC, Hajat S (2020) The effects of temperature on Accident and Emergency Department attendances in London: a time-series regression analysis. Int J Environ Res Public Health 17(6):1957. https://doi.org/10.3390/ijerph17061957

Lee HJ, Jin MH, Lee JH (2016) The association of weather on pediatric emergency department visits in Changwon, Korea (2005–2014). Sci Total Environ. 1;551–552:699–705. https://doi.org/10.1016/j.scitotenv.2016.02.015. Epub 2016 Feb 19. PMID: 26901744

Lin LW, Lin HY, Hsu CY, Rau HH, Chen PL (2015) Effect of weather and time on trauma events determined using emergency medical service registry data. Injury 46(9):1814–1820. https://doi.org/10.1016/j.injury.2015.02.026

Macgregor DM (2003) Effect of weather on attendance with injury at a paediatric emergency department. Emerg Med J 20(2):204–205. https://doi.org/10.1136/emj.20.2.204

Michas F (2023) bAccident and emergency attendances in England 2022/23, by day of week https://www.statista.com/statistics/823104/accident-and-emergency-attendances-day-of-week-in-england/ Accessed 24 October 2023

O'Keeffe C, Mason S, Jacques R, Nicholl J (2018) Characterising non-urgent users of the emergency department (ED): a retrospective analysis of routine ED data. PLoS ONE 13:e0192855. https://doi.org/10.1371/journal.pone.0192855

Ou DK, To TP, Taylor DM (2005) Weather patients will come? Med J Aust 183(11–12):5–19. https://doi.org/10.5694/j.1326-5377.2005.tb00077.x

Parsons N, Odumenya M, Edwards A, Lecky F, Pattison G (2011) Modelling the effects of the weather on admissions to UK trauma

units: a cross-sectional study. Emerg Med J 28:851e855. https://doi.org/10.1136/emj.2010.091058

Ramgopal S, Dunnick J, Owusu-Ansah S, Siripong N, Salcido DD, Martin-Gill C (2019) Weather and temporal factors Associated with Use of Emergency Medical services. Prehosp Emerg Care 23(6):802–810. https://doi.org/10.1080/10903127.2019.1593563

Robertson GAJ, Marsh AG, Gill SL, Martin D, Lowe DJ, Jamal B (2022) The influence of heatwave temperatures on fracture patient presentation to hospital. Injury 53(10):3163–3171. https://doi.org/10.1016/j.injury.2022.07.007

Salas EB (2023) Monthly average daily temperatures in the United Kingdom 2015–2023 https://www.statista.com/statistics/322658/monthly-average-daily-temperatures-in-the-united-kingdom-uk/. Accessed11 October 2023

Sun Y, Heng B, Tay SY, Seow E (2009) Forecasting daily attendances at an emergency department to aid resource planning. BMC emergency medicine. 9. 1. https://doi.org/10.1186/1471-227X-9-1

Weston-Simons J, Jack CM, Doctor C, Brogan K, Reed D, Ricketts D (2012) The impact of snow on orthopaedic trauma referrals. Injury 43(7):1033–1036. https://doi.org/10.1016/j.injury.2011.12.018

Yeung M, Schweitzer C, Wang D, Weaver C, Lang E (2020) Orthomageddon: a retrospective cohort study of weather-dependent variations in emergency department volume in a Canadian city. Am J Emerg Med 38(4):815–818. https://doi.org/10.1016/j.ajem.2019.12.009