DANISH MEDICAL JOURNAL

Original Article

Dan Med J 2021;68(10):A12200934

A population-based study of seasonal variation in children's fractures

Anja R. Lund[1, 3], Christian Faergemann[1, 2, 3] & Jens M. Lauritsen[1, 3]

1) Accident Analysis Group, Department of Orthopaedics and Traumatology, Odense University Hospital, 2) Section for Paediatric Orthopaedics, Department of Orthopaedics and Traumatology, Odense University Hospital, 3) Department of Clinical Medicine, University of Southern Denmark, Denmark

Dan Med J 2021;68(10):A12200934

ABSTRACT

INTRODUCTION Few Scandinavian studies have studied seasonal variations in paediatric fractures, and the studies that have focused on individual fracture sites. Furthermore, their findings do not coincide as they have described peaks in different seasons. Therefore, we described seasonal variation in the incidence rate (IR) of all paediatric fractures in the 1996-2019 period within a Danish population.

METHODS We extracted data from the existing emergency room register at Odense University Hospital and included all fractures sustained by children aged 0-14 years and living in Odense Municipality. Seasonal and monthly IR were calculated using population counts stratified by age, gender and fracture site.

RESULTS We recorded a significant increase in IR in spring and summer, except for a drop in July. For boys, the IR ranged from 206 in December to 404 per 10,000 person-years in June. For girls, the incidence ranged from 156 in December to 317 in May. Fractures were more frequent in the upper extremities and were up to six-fold more frequent in the epiphysis and metaphysis than in the shafts. All fracture sites showed a peak in spring and summer, suggesting that all fracture sites are subject to seasonal variation, especially the ones near the epiphysis.

CONCLUSIONS The fracture peak observed in spring and summer corresponds to an increase in physical activity. The low incidence registered in July corresponds to a low level of sport activities during the summer vacations and families going on vacation in the countryside or travelling abroad. This study gives useful information for coordinating the right resources at hospitals.

FUNDING none

TRIAL REGISTRATION not relevant

Paediatric fractures are common. A recent Danish study found the annual incidence rate (IR) of fractures in children aged 0-15 years to be 255 per 10,000 person-years [1]. Another recent Scandinavian study described a risk of sustaining a fracture before 17 years of age as 34% and an overall IR of 208 per 10,000 person-years [2]. Other Scandinavian studies of children's fracture have shown a fracture incidence in the range 154-179 per 10,000 person-years [3, 4].

The fracture incidence varies with the seasons. Most studies have shown an increase in spring and summer [1, 2, 5-13]. Other studies have reported a peak in autumn and winter [5, 12, 14]. Segal et al. described how warm weather, but with the temperatures not exceeding 28 °C, increased the fracture incidence, and a high incidence is therefore seen in spring and autumn alike [12]. A study focusing on distal forearm fractures showed a peak in

winter due to popular winter activities, e.g. ice-skating [14]. The climate affects the seasonal variation as the studies with an autumn peak have originated from warmer climates [5, 12].

The different climates, cultures and shifts in popular trends over time make it difficult to apply the findings from previous studies to other locations, making a geographically specific study necessary to plan appropriate preventive actions such as coordinating the right medical resources and timing the publication of safety campaigns. Few previous Scandinavian studies have investigated seasonal variation, and three studies that have explored the topic focused on one fracture type only; two on femoral shaft fractures and one on distal forearm fractures [8, 11, 14]. Two other Swedish studies mentioned seasonal variation briefly, both with all fractures overall grouped into one category [1, 2]. To our knowledge, no previous Scandinavian study has investigated seasonal variation in more than one specific fracture site, and no previous long-term Danish study describing seasonal variation exists.

The purpose of this study was to describe the seasonal variation in the IR of fractures in children living in Odense Municipality and treated at Odense University Hospital (OUH).

METHODS

The population base for this study was Odense Municipality, Denmark, in the period from January 1996 to December 2019. Odense Municipality is a well-defined geographical area with a population of 204,182 in 2019 mainly consisting of the City of Odense [15]. The population of children 0-14 years of age increased from 29,979 in 1996 to 31,785 in 2019 [15].

Data were extracted from the emergency department (ED) register and included all children aged 0-14 years living in the municipality who had been treated for any bone fracture in the ED at OUH in the period from January 1996 to December 2019. The ED at OUH is the only ED in the municipality. The qualified staff at the ED did all registration in a similar way throughout the study period. Diagnoses were coded according to the International Classification of Diseases – tenth version (ICD-10).

In Denmark, all registered residents have a unique civil registration number (CPR number), which follows each individual throughout their entire life. We used the CPR number to identify individuals with more than one contact due to the same fracture. In cases with more than one contact to the ED for the same fracture, only the first incident was included. For all cases, information regarding gender, age, date of treatment and diagnoses was obtained from the patient registration system.

We defined fractures as any bone injury including epiphyseal fractures (Salter Harris types), avulsions, Tillaux/triplane fractures, complete and incomplete (bowing, greenstick and torus) fractures. Only radiographically confirmed fractures were included. Fractures included corresponded to the ICD-10 codes DSx2x. We defined three age groups; 0-4 years, 5-9 years and 10-14 years, stratified according to the psychosocial and physiological steps in children's development. As the 10-14-year age group was expected to record most fractures and have the highest seasonal variation, further detailed analysis was restricted to this age group.

We calculated the IR in four seasons, defined as spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). July was analysed separately due to the low number of fractures recorded in July. Additionally, the IRs were calculated in three time periods representing the development over time; the first four years (1996-1999), the four middle years (2006-2009) and the final four years (2016-2019). To examine the seasonal variation in fractures that could affect children's growth, fracture sites were divided into four groups: fractures of epiphysis or metaphysis in the upper extremities (ICD-10: DS420, DS421, DS422, DS424, DS520, DS521, DS525, DS526), shaft fractures in the upper extremities (DS423, DS522,

DS523, DS524), fractures of epiphysis or metaphysis in the lower extremities (DS720, DS721, DS722, DS724, DS820, DS821, DS823, DS825, DS826, DS827, DS828) and shaft fractures in the lower extremities (DS723, DS822, DS824). Fractures of the hands, feet and axial skeleton were excluded from this part of analysis.

Statistics

Using population counts, we calculated age and gender-specific monthly and seasonal IR using the Clopper-Pearson method by dividing the annual population counts by 12 and 4, respectively. We extracted population counts as population at risk from Statistics Denmark [15]. The IRs were calculated as densities in a dynamic cohort allowing subjects to enter and leave the cohort by migration. Children with fractures were not excluded from the population at risk. EpiData Analysis V1.7 was used for all statistical analyses.

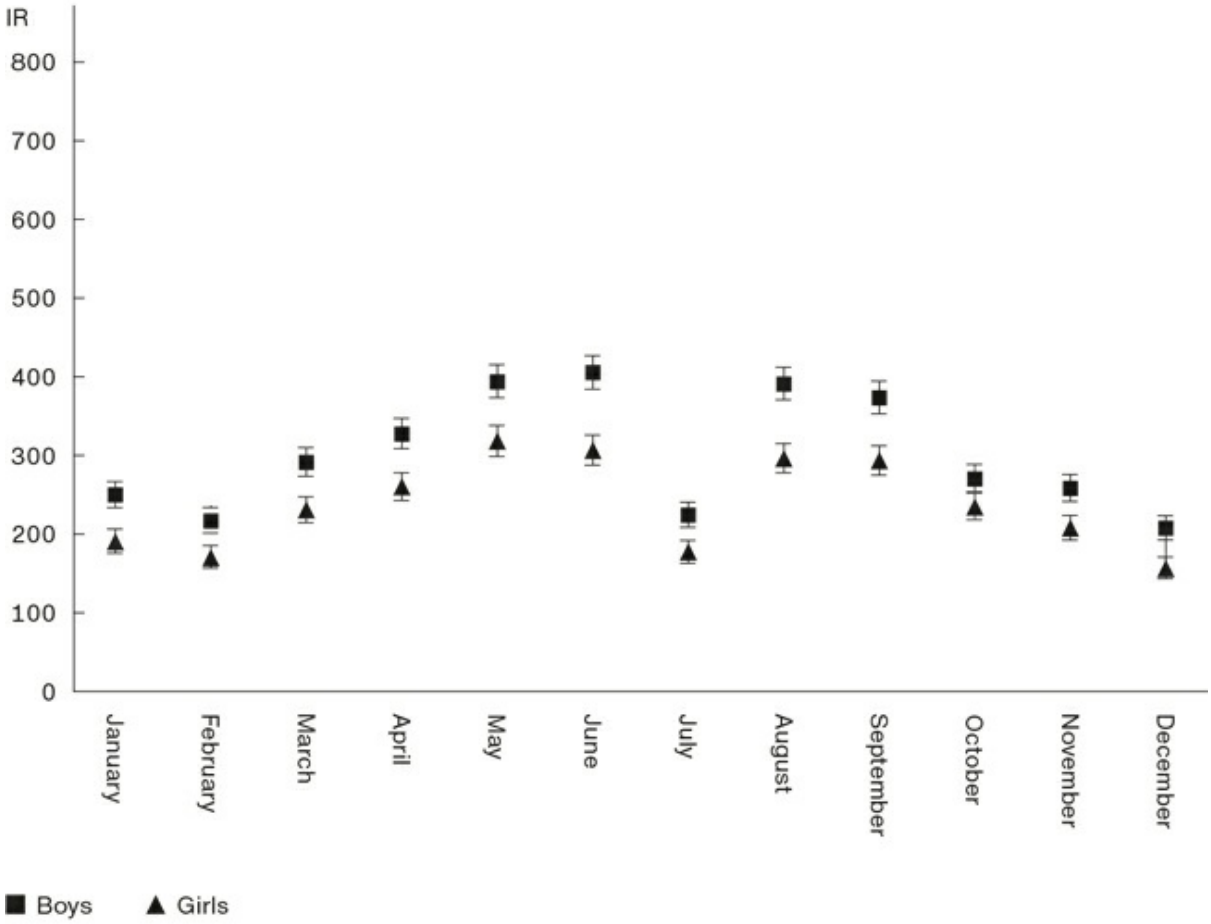
Trial registration: not relevant.

RESULTS

During the 24-year study period, a total of 20,654 fractures were included. The overall IR was 268 per 10,000 person-years (95% confidence interval (CI): 265-272). Boys accounted for 11,818 fractures (57%, IR = 300 (95% CI: 294-305)) and girls for 8,836 (43%, IR = 236 (95% CI: 231-240)). The seasonal percentages (boys/girls) were winter 61%/39%, spring 57%/43%, summer 58%/42% and autumn 56%/44%. Overall, 9,651 (47%) fractures were in the 10-14-year age group (IR = 397 (95% CI: 390-405)), 7,013 (34%) in the 5-9-year age group (IR = 273 (95% CI: 266-279)) and 3,990 (19%) in the 0-4-year age group (IR = 148 (95% CI: 144-153)). The median age was nine (range: 0-14) years for both boys and girls.

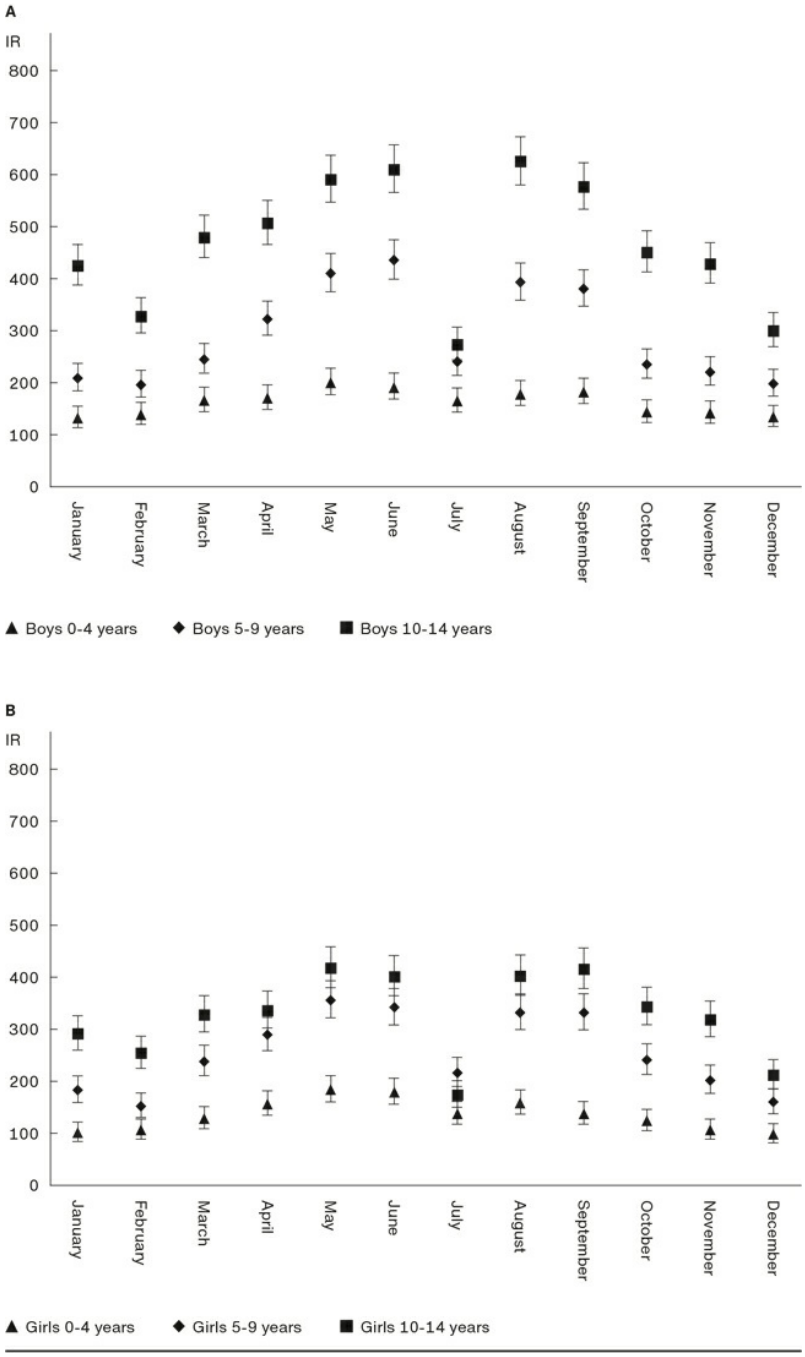
The gender-specific monthly IR varied during seasons (**Figure 1**). Both boys and girls had a significantly higher IR in spring and summer, except for July. For boys, the highest IR was recorded in June (404 per 10,000 person-years (95% CI: 383-426)) and the lowest was in December (206 (95% CI: 192-222)). For girls, the highest incidence was recorded in May (317 (95% CI: 298-337)) and the lowest in December (156 (95% CI: 142-170)).

FIGURE 1 The monthly incidence rate per 10,000 person-years (IR) with 95% confidence intervals of paediatric fractures, stratified by gender.



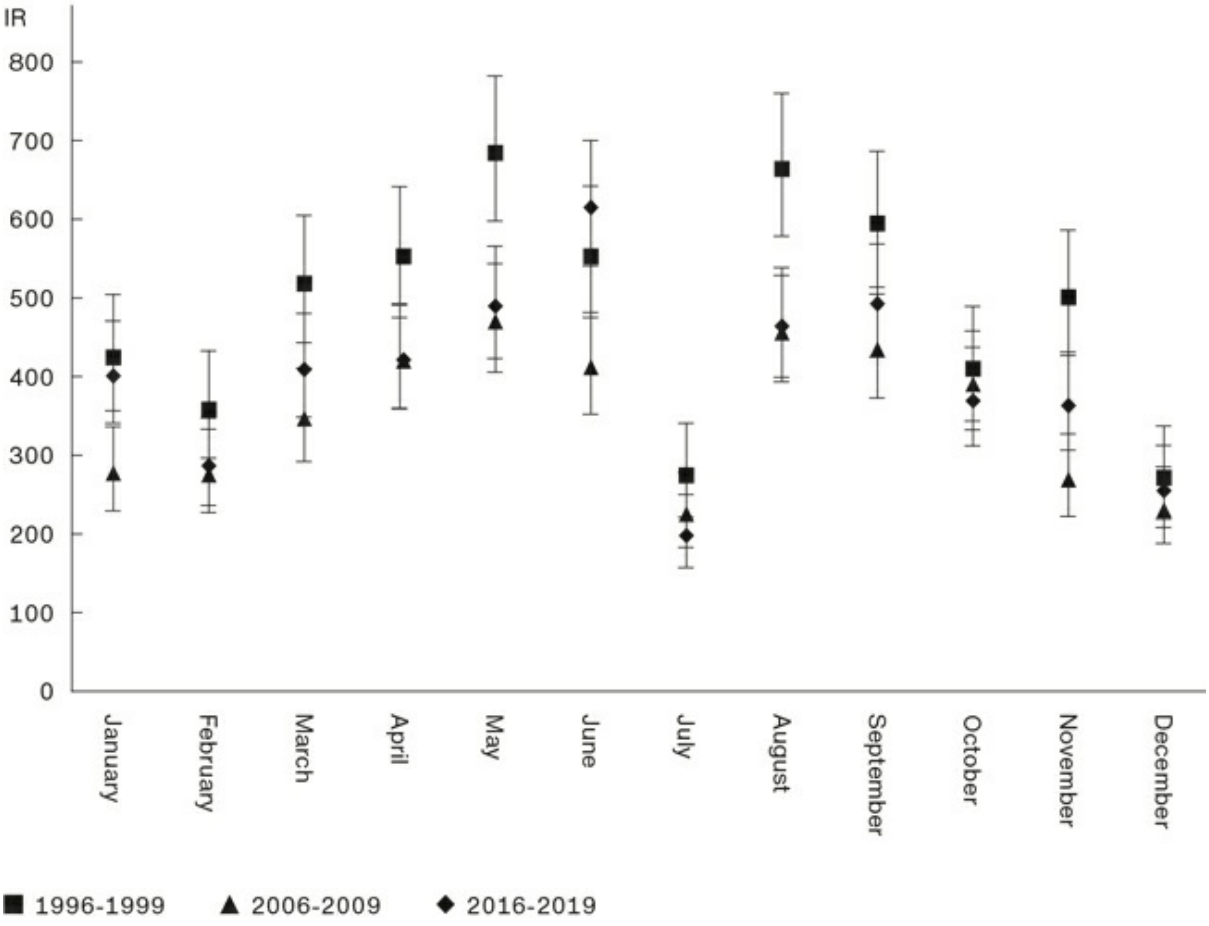
The seasonal variation in monthly IR varied with age groups (**Figure 2**). The youngest age group showed only slight seasonal variation with the highest IR being recorded in May. Significant seasonal variation was recorded in the older age groups. Among boys in the 5-9-year age group, the IR varied from 195 (95% CI: 171-222) in February to 435 (95% CI: 398-474) in June. Similarly, among girls in the same age group, the IR varied from 153 (95% CI: 131-178) in February to 358 (95% CI: 324-395) in May. In the oldest age group, the IR varied from 272 (95% CI: 242-305) in July to 626 (95% CI: 581-674) in August for boys, and from 174 (95% CI: 150-202) in July to 419 (95% CI: 382-461) in May for girls.

FIGURE 2 The monthly incidence rate per 10,000 person-years (IR) with 95% confidence intervals of paediatric fractures for boys (A) and girls (B) in different age groups.



No significant development in the monthly IR was seen during the study period (**Figure 3**). All three periods roughly followed the same pattern with July and the three winter months having the lowest IR.

FIGURE 3 The monthly incidence rate per 10,000 person-years (IR) with 95% confidence intervals of paediatric fractures in the age group 10-14 years in three time periods 1996-1999, 2004-2007 and 2016-2019.



All four fracture sites, except the shaft in the lower extremities, showed a significantly higher IR in spring, summer and autumn than in winter (**Table 1**). For the shaft fractures in the lower extremities, only spring had a significantly higher fracture IR than winter. Shaft fractures in the upper extremities had a significantly higher incidence in summer than in other seasons. Epiphyseal and metaphyseal fractures in the upper extremities recorded significantly higher IR in spring and summer (not including July) than in autumn. This group of fractures is several times more frequent, with a spring IR six fold higher than the second-most frequent group in the spring.

TABLE 1 The seasonal incidence rates per 10,000 person-years (with 95% confidence intervals) of paediatric fractures, stratified by different fracture sites and codes from the International Classification of Diseases – tenth version (ICD-10).

Fracture group	ICD-10	Spring	June and August	July	Autumn	Winter
Upper extremities						
Epiphyseal and metaphyseal	DS420, DS421, DS422, DS424, DS520, DS521, DS525, DS526	554 (533-574)	796 (765-829)	436 (402-471)	476 (458-496)	319 (303-335)
Shaft	DS423, DS522, DS523, DS524	58 (52-66)	103 (92-116)	60 (48-74)	52 (46-59)	30 (26-36)
Lower extremities						
Epiphyseal and metaphyseal	DS720, DS721, DS722, DS724, DS820, DS821, DS823, DS825, DS826, DS827, DS828	90 (82-98)	112 (100-125)	67 (54-82)	75 (68-84)	51 (45-57)
Shaft	DS723, DS822, DS824	35 (30-40)	36 (29-44)	23 (16-32)	26 (22-31)	25 (21-29)

DISCUSSION

Overall, seasonal variation was observed in children's fractures with an increase in spring and summer, except for a massive drop in July. No development in IR was seen in the course of the study period. Fractures were more frequent in the upper extremities than in the lower extremities, and epiphyseal and metaphyseal fractures were more frequent than shaft fractures. All fracture site groups showed a peak in spring, suggesting that all fracture sites on the extremities have seasonal variation, especially epiphyseal and metaphyseal fractures.

The peak recorded in spring and summer corresponds to the findings reported by most previous studies [1, 2, 5-13]. A Danish study describing femoral shaft fractures showed a peak in summer, which is consistent with our findings [8]. The only other Danish study describing seasonal variation in distal forearm fractures showed a peak in winter, which runs contrary to our findings [14]. The study suggested sledding, ice skating and skiing as possible reasons for the observed winter peak; these activities are no longer as popular in Denmark as winter weather has become milder and winter activities are therefore less accessible [16]. As our study found all fracture sites to have the lowest IR in winter, the peak in winter does not seem to be unique for Denmark, but unique only to the winter of 1985. January 1985 was exceptionally cold, and the winters of 1984/1985 and 1985/1986 were registered as ice winters [16]. This may explain the high IR found in January 1985 [14]. No ice winters have been registered in the course of our study period [16].

A massive drop in the IR was found in July in the two oldest age groups. In the 10-14-year age group, July recorded the lowest IR of all months. We registered this drop throughout the entire study period. No other study seems to find such a substantial a drop in July. Even so, a decrease was found in some of the previous studies [1, 2, 6, 12]. Segal et al. suggested that four factors may contribute to the phenomenon: change in behaviour, hot weather, travelling and weather-induced alterations in bone health [12]. In Denmark, the school holidays fall in July, and July is the month in which most families travel, either abroad or out of the larger cities. This may potentially reduce the general workload at hospitals like the OUH and increase the workload at smaller hospitals nearer to vacation areas in July. A previous study showed how falls and playing accounted for most of children's fractures and how sports accounted for the majority of the remaining fractures, leaving only a small part to be caused by traffic accidents [3]. A Swedish study described how playing was the most common activity at injury during the first decade of life and how sports was the most common among teenagers [2]. This suggests that behaviour and physical activity play a considerable role in determining fracture risk. During the school holidays, most sports are paused and children do not uphold their normal daily routines. This may potentially decrease children's physical activity level and be a contributing factor to the fracture incidence drop observed in July.

Papers describing seasonal variation in children's physical activities show how the activity is at its highest in spring, suggesting that the peak in fractures may be associated with the level of child activity [17, 18]. A Danish study showed that 6% of reports to the ED during their study period was related to the use of trampolines, and trampolines are expected to be one of the reasons why the number of fractures increases in summer [19].

We found that all fracture sites on extremities were subject to seasonal variation, and that fractures in the epiphysis or metaphysis had a higher IR. Fractures near growth plates may damage the growth plate, leading to angular deformity and/or limb length discrepancy. Based on our study, we suggest that safety campaigns aiming to reduce the fracture incidence in children should be released in the early spring before the seasonal fracture IR peak.

The strength of this study is the extensive study period, which minimises the impact of any exceptionally cold winter or warm summer on seasonal IR. Other strengths include the geographically well-defined municipality, the valid population data and the quality-assured registration practice in the ED.

The study may also have some limitations. As this was a register-based study, data may be subject to registration

error. However, all information was registered by trained staff and diagnoses were made by trained physicians. The cases included were children seeking medical attention at the ED of the OUH. We have no information to establish whether children in the population received treatment at other hospitals or at general practitioners. The latter option is considered negligible as general practitioners do not have access to

X-ray equipment. Some children's fractures may occur on holidays and they may therefore be treated elsewhere. These fractures are not included, which may partly explain the low incidence recorded in July.

CONCLUSIONS

This study adds important information about seasonal variation in workload in Danish EDs, which is important when coordinating the right resources at the hospitals. Furthermore, the study adds important information for the planning of preventive campaigns aiming to reduce the number of fractures sustained by children. This study does not include the effects of campaigns, but may be used as a basis for future studies, which we recommend should be conducted. More studies are warranted to obtain results reflecting other climates and cultural settings.

Correspondence *Christian Faergemann.* E-mail: Christian.Faergemann@rsyd.dk

Accepted 20 August 2021.

Conflicts of interest none. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

References can be found with the article at ugeskriftet.dk/dmj

Cite this as Dan Med J 2021;68(10):A12200934

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