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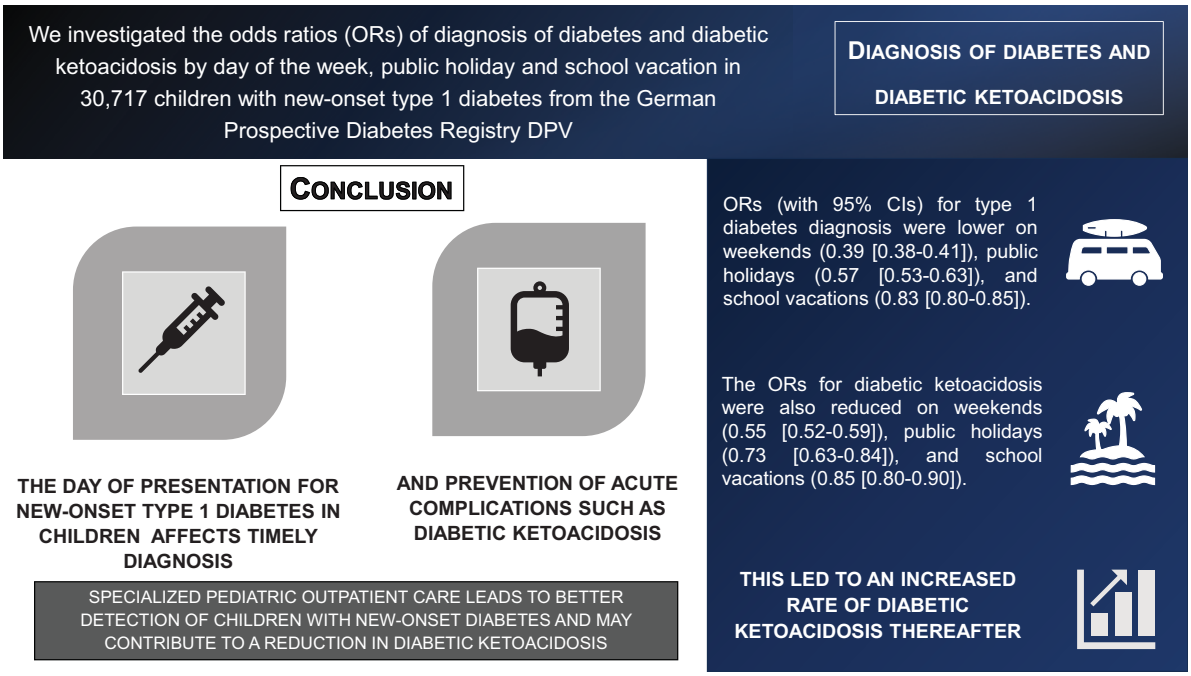

ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  We wanted to determine whether the day of the week on which children present affects the timely diagnosis of type 1 diabetes and prevent diabetic ketoacidosis.
- **What is the specific question(s) we wanted to answer?**
  We investigated the influence of day of presentation on diabetes diagnosis and rate of diabetic ketoacidosis.
- **What did we find?**
  Diabetes and diabetic ketoacidosis were less likely to be diagnosed on weekends, public holidays, and school vacations than on weekdays. This led to an increased rate of diabetic ketoacidosis thereafter.
- **What are the implications of our findings?**
  Improved knowledge of the clinical signs and symptoms of diabetes in children in primary and acute care would likely improve the detection of children with new-onset diabetes and reduce the rate of diabetic ketoacidosis.

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Clemens Kamrath,[1] Marina Sindichakis,[2] Marie Auzanneau,[3,4] Silke Schmid,[5] Hugo Segerer,[6] Valentina Lahn,[7] Sven Golembowsky,[8] Dorothee Roessner-Cold,[9] Kristina Rauh,[10] Ulf Manuwald,[11] and Reinhard W. Holl[3,4]

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BRIEF REPORT

OBJECTIVE

Whether the day of the week on which the child presents affects timely diagnosis and risk of diabetic ketoacidosis (DKA) in children with new-onset type 1 diabetes (T1D) is not known.

RESEARCH DESIGN AND METHODS

We used data of 30,717 children with new-onset T1D during the last 10 years from the German Prospective Diabetes Registry. We determined the odds ratios of T1D diagnosis and DKA on a weekday, public holiday, and school vacation.

RESULTS

Compared with workdays, the odds ratios of being diagnosed with T1D were lower on weekends (0.39 [95% CI, 0.38–0.41]), public holidays (0.57 [0.53–0.63]), and school vacations (0.83 [0.80–0.85]). The odds of DKA diagnosis were also reduced on weekends (0.55 [0.52–0.59]), public holidays (0.73 [0.63–0.84]), and school vacations (0.85 [0.80–0.90]). Results did not change during the coronavirus 2019 pandemic.

CONCLUSIONS

New-onset T1D and DKA in children are more often diagnosed during weekdays than weekends and holidays.

Diabetic ketoacidosis (DKA) at the onset of type 1 diabetes (T1D) represents a serious complication that occurs because of delayed diagnosis and initiation of insulin replacement therapy (1,2). Prevention of DKA is an important goal, but recent data indicate increasing DKA rates (3,4). Delayed initiation of insulin treatment may be due to lack of knowledge of diabetes symptoms by either parents or caregivers, or failure to recognize early signs of diabetes in children presenting to primary health care providers (5).

Primary care for children differs between weekdays and weekends or public holidays. On weekdays, medical care for children in Germany is ensured by regular consultation hours in pediatric practices, while, on weekends and public holidays, the general medical on-call service of the statutory health insurance plays a decisive role for urgent medical needs.

The aim of this study was to investigate the influence of day of presentation on diabetes diagnosis and DKA rate.

[1]*Center of Child and Adolescent Medicine, Justus Liebig University, Giessen, Germany*
[2]*Hospital for Children and Adolescents, Klinikum Traunstein, Traunstein, Germany*
[3]*Institute of Epidemiology and Medical Biometry, Computer-Assisted Quality Assurance in Medicine, Ulm University, Ulm, Germany*
[4]*German Center for Diabetes Research, Munich-Neuherberg, Germany*
[5]*Dritter Orden Clinic, Munich, Germany*
[6]*University of Regensburg Children's Hospital St. Hedwig, Regensburg, Germany*
[7]*Children's Hospital Hamburg-Altona, Hamburg, Germany*
[8]*Children's Hospital Sana-Clinic Berlin-Lichtenberg, Berlin, Germany*
[9]*Gilead Child Center Bielefeld, Bielefeld, Germany*
[10]*Children's Hospital Chemnitz, Chemnitz, Germany*
[11]*Faculty of Applied Social Sciences, University of Applied Sciences, Dresden, Germany*

Corresponding author: Clemens Kamrath, clemens.kamrath@paediat.med.uni-giessen.de

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C.K. and M.S. contributed equally to this study.

See accompanying article, p. 646.

RESEARCH DESIGN AND METHODS

Data Source and Study Population

We used data from the German prospective diabetes follow-up registry (DPV registry) of children and adolescents aged 0.5 to <18 years at diagnosis (±14 days) of T1D between 1 January 2013 and 31 December 2022. The nationwide coverage of the DPV registry for pediatric patients with T1D in Germany has been estimated at 93% (6). Data are documented at each participating institution using the standardized DPV documentation software (7). The ethics committee of Ulm University (Ulm, Germany) approved the analysis of anonymized data from the DPV registry (ethics approval 314/21); local review boards approved data collection.

Variables

Demographic data included age at diabetes onset, sex, and immigrant background (patient or at least one parent born outside Germany).

DKA was defined as pH <7.3 and/or serum bicarbonate <15 mmol/L and as severe if pH was <7.1 and/or bicarbonate was <5 mmol/L (1).

The variables public holiday and school vacation were evaluated separately for each federal state. Public holidays were defined as work-free days (excluding weekends), regardless of religious or political background. Delayed treatment initiation was defined as time interval ≥1 day between diagnosis and treatment initiation.

Statistical Analysis

Unadjusted outcomes were compared using Wilcoxon rank sum test for continuous outcomes or Fisher exact test for dichotomous outcomes.

Logistic regression models were used to determine the odds ratio (OR) of diagnosis of diabetes or DKA on different days of the week, adjusted for age groups (<6 years, 6 years to <12 years, and 12 to <18 years), sex, and immigrant background (yes/no).

P values were adjusted for multiple testing using the Bonferroni-Holm method.

A two-sided *P* value <0.05 was considered statistically significant. All analyses were performed with SAS version 9.4 (SAS Institute Inc., Cary, NC).

Data Availability

Access to the data is possible by remote data processing upon request.

Table 1—Characteristics of patients with new-onset T1D from 2013 to 2022

Variable	Total observation period	Pre-COVID-19 (2013–2019)	Post-COVID-19 (2020–2022)
Patients, *N*	30,717	19,683	11,034
Males, *N* (%)	16,918 (55.1)	10,747 (54.6)	6,170 (56.0)
Females, *N* (%)	13,799 (44.9)	8,936 (45.4)	4,863 (44.0)
Age (years), median (interquartile range)	9.6 (5.9–12.9)	9.8 (6.1–13.0)	9.3 (5.6–12.6)
Immigrant background, *N* (%)	7,588 (24.7)	4,702 (23.9)	2,887 (26.2)
DKA$ at diabetes onset, *N* (%)	7,915 (25.8)	4,287 (21.8)	3,627 (32.9)
Severe DKA‡ at diabetes onset, *N* (%)	2,790 (9.1)	1,445 (7.3)	1,345 (12.2)
Delayed treatment initiation,§ *N* (%)	2,589 (9.1)	1,779 (9.9)	809 (7.8)

$pH <7.3 and/or serum bicarbonate <15 mmol/L at treatment initiation. ‡pH <7.1 or bicarbonate <5 mmol/L at treatment initiation. §Time interval of ≥1 day between diagnosis and treatment initiation. For this subgroup analysis of delayed treatment initiation, the following patient data were available for analysis: total observation period *N* = 28,310, pre-COVID-19 (2013–2019) *N* = 18,037, and post-COVID-19 (2020–2022) *N* = 10,273.

RESULTS

We analyzed data of 30,717 children and adolescents (55.1% males) with new-onset T1D. DKA at diagnosis of T1D was present in 7,916 children (25.8%). Table 1 provides an overview of the study cohort.

T1D was diagnosed on weekdays in 86.6% of children with new-onset T1D (i.e., mean 17.3% per day), with the highest proportion at the beginning of the week—Monday and Tuesday accounting for 40.9% of all diabetes diagnoses, and 13.4% at weekends (i.e., in mean 6.7% per day) (Table 2). This corresponds to an adjusted OR of diabetes diagnosis on weekends compared with weekdays of 0.39 (95% CI, 0.38–0.41; $P < 0.001$). Furthermore, T1D was less likely to be diagnosed on public holidays (OR 0.57 [0.53–0.63; $P < 0.001$]) and during school vacations (OR 0.83 [0.80–0.85; $P < 0.001$]) than on workdays (Table 3).

A total of 6,503 out of 7,915 cases of new-onset diabetes with DKA (82.2%) were diagnosed on weekdays (including 3,129 cases [39.5%] on Mondays and Tuesdays), compared with 1,412 cases on weekends (17.8%) (Table 2). This corresponds to an adjusted OR of DKA diagnosis on weekends compared with weekdays of 0.55 (95% CI, 0.52–0.59; $P < 0.001$). The adjusted OR of DKA diagnosis during a public holiday and school vacation compared with a workday was 0.73 (0.63–0.84; $P < 0.001$) and 0.85 (0.80–0.90; $P < 0.001$), respectively (Table 3). Diabetes diagnoses decreased more than DKA diagnoses during weekends and holidays compared with weekdays. This resulted in a higher proportion of DKA among those diagnosed with

Table 2—Characteristics of patients with new-onset T1D from 2013 to 2022 related to the day of the week of diabetes diagnosis

Day of the week	Diabetes diagnosis	Delayed treatment initiation§	DKA$	Severe DKA‡
Monday, *N* (%)	6,792 (22.1)	491 (19.0)	1,752 (22.1)	540 (19.4)
Tuesday, *N* (%)	5,763 (18.8)	414 (16.0)	1,377 (17.4)	429 (15.4)
Wednesday, *N* (%)	4,382 (14.3)	370 (14.3)	1,089 (13.8)	366 (13.1)
Thursday, *N* (%)	5,228 (17.0)	394 (15.3)	1,197 (15.1)	374 (13.4)
Friday, *N* (%)	4,441 (14.5)	364 (14.1)	1,088 (13.8)	379 (13.6)
Saturday, *N* (%)	1,985 (6.5)	263 (10.2)	650 (8.2)	309 (11.1)
Sunday, *N* (%)	2,126 (6.9)	286 (11.1)	762 (9.6)	393 (14.1)

The percentage refers to the proportion per weekday. §Time interval of ≥1 day between diagnosis and treatment initiation. $pH <7.3 and/or serum bicarbonate <15 mmol/L at hospital admission. ‡pH <7.1 or bicarbonate <5 mmol/L at treatment initiation.

Table 3—Adjusted probabilities of diagnosis of diabetes and of DKA by day of presentation

	Total observation period OR (95% CI)	Pre-COVID-19 OR (95% CI)	Post-COVID-19 OR (95% CI)
Probability of diabetes diagnosis			
Weekends versus weekdays	0.39 (0.38–0.41)	0.39 (0.37–0.40)	0.40 (0.38–0.43)
School vacation versus workdays	0.83 (0.80–0.85)	0.84 (0.81–0.88)	0.80 (0.76–0.85)
Public holiday versus workdays	0.57 (0.53–0.63)	0.61 (0.54–0.68)	0.51 (0.44–0.59)
Probability of DKA diagnosis			
Weekends versus weekdays	0.55 (0.52–0.59)	0.56 (0.51–0.61)	0.55 (0.50–0.60)
School vacation versus workdays	0.85 (0.80–0.90)	0.88 (0.81–0.95)	0.81 (0.75–0.89)
Public holiday versus workdays	0.73 (0.63–0.84)	0.79 (0.65–0.96)	0.65 (0.52–0.82)

All values of ORs are below 1.0 ($P < 0.001$ for all).

diabetes on weekends and holidays (Fig. 1 and Table 3).

Among those with DKA, 2,790 (35.3%) had severe DKA. Of these, most were diagnosed on Mondays (N = 540 [19.4%]) and Tuesdays (N = 429 [15.4%]) (Table 2).

The proportion of children with delayed treatment initiation was 9.1%. The DKA rate was 28.0% in children treated immediately and 21.2% in those in whom treatment was delayed ($P < 0.001$).

Diabetes diagnoses on weekends, school vacations, and public holidays resulted in higher rates of delayed treatment initiation of 14.4%, 12.4%, and 21.8%, respectively, than diagnoses on weekdays (8.3%) or workdays (8.9%, all $P < 0.001$). The mean time interval between diabetes diagnosis and treatment initiation was 0.31 days on workdays, 0.55 days on weekends, and 1.17 days on public holidays (both $P <$ 0.001 versus workdays).

An increase in the frequency of DKA and severe DKA was observed during the coronavirus 2019 (COVID-19) pandemic (Table 1). However, outcomes were not significantly affected by the pandemic (Table 3).

CONCLUSIONS

This study found lower ORs of diabetes diagnosis, including those with DKA, in children during weekends, public holidays, and school vacations, and a higher proportion at the beginning of the week, probably due to missed diagnoses over the weekend. Therefore, our results imply that a large proportion of patients with new-onset T1D who experience DKA are missed on weekends and holidays.

T1D is the most common form of diabetes in children and adolescents, putting them at high risk of progressing to life-threatening DKA (1). Nevertheless, insulin treatment was not directly initiated after diabetes diagnosis in 9.1% of cases. This is consistent with other reports of delayed insulin treatment (8). Importantly, one in five patients who did not start insulin treatment on the day of diabetes diagnosis developed DKA.

Delayed treatment initiation was more frequent when diabetes was diagnosed on weekends and public holidays. Thus, these cases represent potentially preventable, life-threatening metabolic derangements. Reasons for delayed therapy may include ignorance of the peculiarities of diabetes diagnosis in children with rapid progression to DKA or lack of experience with insulin treatment in children. The higher rate of DKA in those who were treated immediately is likely due to the more severe symptoms in those with DKA,

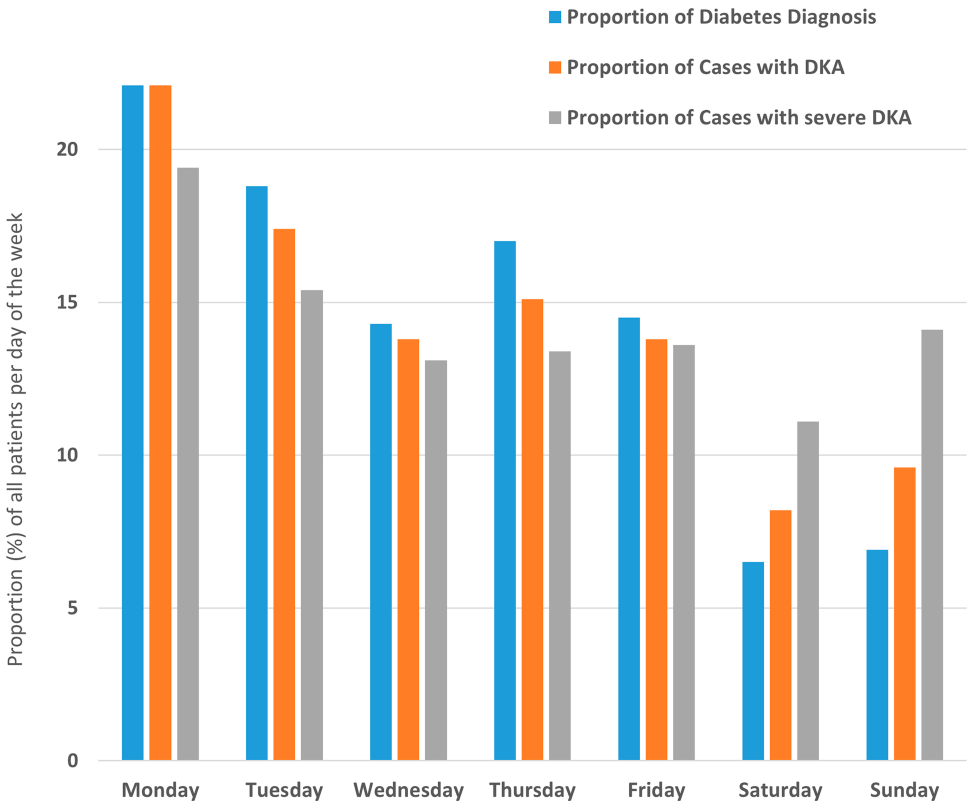

Figure 1—Proportion of diabetes diagnoses, DKA cases, and severe DKA cases by day of week.

making them more likely to receive immediate treatment.

We assume that the differences in the detection of children with new-onset diabetes between the days of presentation are related to both family and primary health care factors. In addition to lack of family awareness, potentially modifiable risk factors for new-onset DKA include low medical suspicion for new-onset diabetes in children, leading to delayed diagnosis (9).

Family factors refer to behavior around weekends and holidays, as families may choose to wait until the next working day to visit the doctor (10). The likelihood of being diagnosed with diabetes was about twice as high during school vacations as during weekends, suggesting that the family factor is not the main contributor.

In Germany, the majority of outpatient care for children and adolescents is provided by pediatricians in primary care settings (11). On weekends and public holidays, outpatient care is provided by the on-call service. This service is staffed by practitioners with a wide range of specialties, therefore—with a few exceptions—specific pediatric expertise is usually not available at these times. Our study suggests that the lack of pediatric expertise outside of regular working hours may be responsible for underdiagnosis of childhood diabetes and missed cases of DKA. Accordingly, a Swedish study found that referral was delayed in a significant proportion of children presenting to primary care with diabetes-related symptoms (5). In addition, children who were not initially evaluated by a pediatrician had a higher DKA rate (12). Compared to international rates, the rate of DKA in children with new-onset diabetes is relatively low in Germany (3). One reason may be the availability of specialized pediatric care during the week (11).

During the COVID-19 pandemic, there was a marked increase in the frequency of DKA and severe DKA (13). However, the pandemic did not have a significant impact on the additional outcomes of our study.

In conclusion, our study shows that new-onset diabetes in children is often undiagnosed during weekends and public holidays, and many cases of DKA are missed. In addition, children with newly diagnosed diabetes often do not receive appropriate treatment promptly during these times. These problems existed before the COVID-19 pandemic and do not explain the increased frequency of DKA during the pandemic.

The results of our study suggest that improved knowledge of the clinical signs and symptoms of diabetes in children in primary and acute care, possibly through continuous specialized outpatient pediatric care, would likely improve the detection of children with new-onset diabetes and reduce the rate of DKA. It is essential to provide comprehensive education about the symptoms and clinical presentation of childhood T1D at various levels, including the general public, childcare facilities, and primary care physicians. This could help raise awareness of the symptoms of T1D (14).

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