Received: 1 July 2021 | Accepted: 14 October 2021

DOI: 10.1002/dmrr.3506

RESEARCH ARTICLE

WILEY

Higher rates of diabetic ketoacidosis and admission to the paediatric intensive care unit among newly diagnosed children with type 1 diabetes in Kuwait during the COVID-19 pandemic

Dalia Al-Abdulrazzaq[1] | Abdullah Alkandari[2] | Fatemah Alhusaini[3] | Naser Alenazi[4] | Unjali P. Gujral[5] | K. M. Venkat Narayan[6] | Hessa Al-Kandari[2,7] | CODeR group

[1]Department of Pediatrics, Faculty of Medicine, Kuwait University, Safat, Kuwait

[2]Department of Population Health, Dasman Diabetes Institute, Kuwait City, Kuwait

[3]Department of Pediatrics, Adan Hospital, Ministry of Health, Hadiya, Kuwait

[4]Department of Pediatrics, New-Ahmadi Hospital, Al Ahmadi, Kuwait

[5]Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, Georgia, USA

[6]Department of Medicine and Nutrition and Health Sciences Program, Rollins School of Public Health, Emory University, Atlanta, Georgia, USA

[7]Department of Pediatrics, Al-Farwaniyah Hospital, Ministry of Health, Al Farwaniyah, Kuwait

Correspondence
Dalia Al-Abdularazzaq, Department of Pediatrics, Faculty of Medicine, Kuwait University, PO Box 24923, Safat 13110, Kuwait.
Email: dalia.alabdulrazzaq@ku.edu.kw

Funding information
Dasman Diabetes Institute, Grant/Award Number: RA 2011-006

Abstract

Introduction: The COVID-19 pandemic might have a multifaceted effect on children with type 1 diabetes (T1D), either directly through infection itself or indirectly due to measures implemented by health authorities to control the pandemic.

Objective: To compare data on children newly diagnosed with T1D in Kuwait during the COVID-19 pandemic to the pre-pandemic period.

Research Design and Methods: We analysed data on children aged 12 years or less registered in the Childhood-Onset Diabetes electronic Registry (CODeR) in Kuwait. Data were incidence rate (IR), diabetic ketoacidosis (DKA), and its severity and admission to the paediatric intensive care unit (PICU).

Results: The IR of T1D was 40.2 per 100,000 (95% CI; 36.0–44.8) during the COVID-19 pandemic period and was not statistically different from pre-pandemic. A higher proportion of incident T1D cases presented with DKA and were admitted to the PICU during the pandemic (52.2% vs. 37.8%: $p < 0.001$, 19.8% vs. 10.9%; $p = 0.002$, respectively). The COVID-19 pandemic was positively associated with presentation of DKA and admission to PICU (AOR = 1.73; 95% CI, 1.13–2.65; $p = 0.012$, AOR = 2.04; 95% CI, 1.13–3.67; $p = 0.018$, respectively). Children of families with a positive history for diabetes were less likely to present with DKA and get admitted to the PICU during the COVID-19 pandemic (AOR = 0.38; 95% CI, 0.20–0.74; $p = 0.004$, AOR = 0.22; 95% CI, 0.08–0.61; $p = 0.004$, respectively).

CODeR group

The Childhood-Onset Diabetes electronic Registry in Kuwait: Dr Hala Al-Sanae, Dr Fahed Al-Jasser, Dr Mariam Qabazard (Amiri Hospital), Dr Maria Al-Mahdi (Al-Adan Hospital), Dr Fawziya Mandani (Sabah Hospital), Dr Ayed Al-Enizi (Jahra Hospital), Dr Iman Al-Basari, Dr Faisal Al-Shawaf (Mubarak Al-Kabeer Hospital), Dr Abeer Al-Tararwa, Dr Dina Ahmad (Farwaniya Hospital).

Conclusion: High rates of DKA at presentation and admission to PICU in incident T1D cases during the COVID-19 pandemic warrant further studies and effective mitigation efforts through increasing awareness, early detection, and timely intervention.

KEYWORDS
children, COVID-19, diabetic ketoacidosis, Kuwait, type 1 diabetes

1 | INTRODUCTION

Drastic measures to control the COVID-19 pandemic at the national or regional level may have disrupted prevention and control efforts targeted towards chronic diseases such as type 1 diabetes (T1D) at the individual, community, and health-care system levels. The government of Kuwait, in response to the World Health Organisation's (WHO) declaration of the pandemic in March 2020, implemented several measures to control the spread of COVID-19. The measures included stay at home orders, the shut-down of non-essential businesses, the closure of the airport and land ports, social distancing protocols, and remote online schooling. Such measures have changed the face of healthcare delivery in the country, as many elective health care procedures were suspended, and outpatient care was shifted to telemedicine. Such measures have been constantly modified according to the pandemic situation in the country.

Therefore, the COVID-19 pandemic might have a multifaceted effect on patients with diabetes in general or T1D in particular, either directly through infection itself[1,2] or indirectly due to measures implemented by health authorities to control the pandemic. The psychological stress associated with measures to control the spread of COVID-19, such as lockdowns, closures of schools, social distancing, and social isolation have been suggested to have a significant role in the onset, progression, and control of diabetes.[3–7] Moreover, compromised access to healthcare during the pandemic, as well as fears of risking infection by obtaining care, may lead to delayed diagnosis, delays in insulin and other treatments, more rapid progression of hyperglycaemia, and higher frequency of diabetic ketoacidosis (DKA) in children with newly diagnosed T1D, thus increasing the risk of morbidity, mortality, and burden on the healthcare system.[8–10]

We compared data on children newly diagnosed with T1D in Kuwait during the first 12 months of the ongoing COVID-19 pandemic to the 12 months immediately before the pandemic. Data on T1D incidence, DKA, and its severity as well as admission to the paediatric intensive care unit (PICU) were evaluated.

2 | RESEARCH DESIGN AND METHODS

We analysed data on children aged 12 years or less (official age range definition of paediatric patients in the country) registered in the Childhood-Onset Diabetes electronic Registry (CODeR) in Kuwait. CODeR is a prospective population-based diabetes registry and is a country-wide surveillance system in Kuwait, with validated high ascertainment. CODeR was established in 2011 and is maintained by Dasman Diabetes Institute (DDI) in collaboration with the Ministry of Health (MOH).[11,12] Data on newly diagnosed T1D among children aged 6 months to 12 years during the COVID-19 pandemic period (12 months, starting from the first confirmed case of COVID-19 in Kuwait on 24 February 2020, until 23 February 2021) were compared with those diagnosed during the same period in the previous 12 months (from 24 February 2019 till 23 February 2020). Children younger than 6 months were excluded due to the diagnosis of neonatal diabetes in this age group.

Data were extracted using standard registry data forms. The forms included baseline information at the time of diagnosis such as demographic information, anthropometric measures (weight, height, and body mass index [BMI]) expressed as standard deviation (SDS) z-scores according to WHO child growth standards.[13] Information on PICU admission, family history of diabetes in first degree relatives, haemoglobin A1C (HbA1C) and venous gas (pH and bicarbonate in mmol/L) were also collected. The 2018 International Society of Paediatric and Adolescent diabetes (ISPAD) guidelines[14] were used to confirm diagnosis of T1D in registered children that is, characterised by the presence by one or more pancreatic antibodies. DKA was defined as venous pH < 7.3 or serum bicarbonate <15 mmol/L and further categorised as mild (venous pH < 7.3, serum bicarbonate <15 mmol/L), moderate (pH < 7.2, serum bicarbonate <10 mmol/L) or severe (pH < 7.1, serum bicarbonate <5 mmol/L).[10] To estimate incidence rate (IR), population at risk was identified as the total number of children aged 12 years or less living in Kuwait as provided by the Kuwait Census Bureau on 1 January 2020.

Statistical analysis was performed on GraphPad Prism, version 8 (San Diego, CA, USA), STATA software version 13.1 and R-Studio. Differences with *p*-value of less than 0.05 were considered statistically significant. All continuous variables were non-normally distributed in this data set and therefore expressed as median (interquartile range: IQR). The Mann-Whitney *U* test was used to test for the differences in continuous variables while Pearson's chi-squared test was used to test for differences in categorical variables. Multiple logistic regression was used to investigate the effect of the COVID-19 pandemic on DKA, severity of DKA, and PICU admission. In this analysis, we created an indicator variable (1 = during COVID-19 pandemic and 0 = pre-pandemic) to be the main explanatory variable while DKA (1 = yes 0 = no) was a main outcome variable. Age, gender, BMI z-score, and family history of diabetes were all considered potential confounders (Table 2). The same analysis was repeated with severe DKA (1 = yes 0 = no) and PICU admission (1 = yes

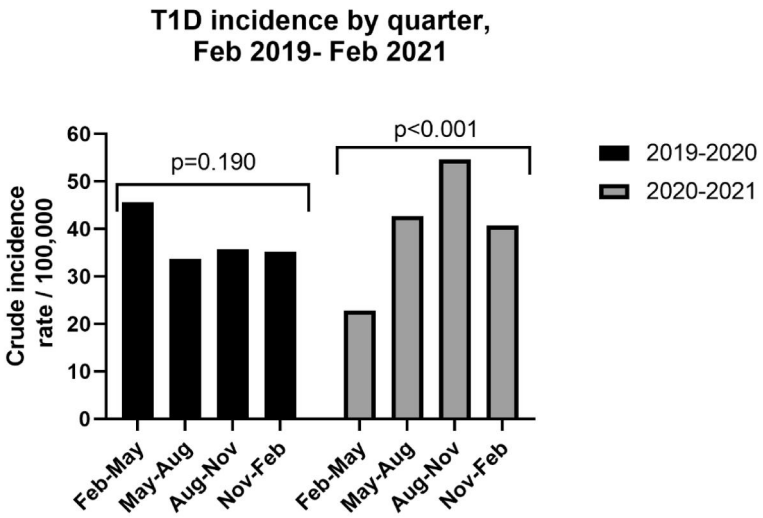

FIGURE 1 Incidence of type 1 diabetes in children aged 12 years or younger by 3-month interval (quarter) during the COVID-19 pandemic period (2019–2020) in comparison to the pre-pandemic period (2020–2021)

TABLE 1 Baseline characteristics of children newly diagnosed with T1D in Kuwait during the COVID-19 pandemic period[a] in comparison to the pre-pandemic period[b]

	Pre-pandemic period (2019–2020)	COVID-19 pandemic period (2020–2021)	*p* value
Newly diagnosed, n	303	324	-
Crude T1D incidence/100,000 (95% CI)	37.6 (33.6–42.1)	40.2 (36.0–44.8)	0.400
Male, *n* (%)	150 (49.5)	151 (46.6)	0.468
Median age, years (IQR)	8.0 (5.3–9.9)	8.2 (5.6–10.0)	0.655
Median HbA1C, % (IQR)	11.5 (9.9–12.6)	11.8 (10.4–13.0)	**0.019**
BMI, z-score (IQR)	0.25 (−0.9–1.4)	−0.3 (−1.6–1.3)	0.066
Admitted to PICU, *n* (%)	33 (10.9)	64 (19.8)	**0.002**
Family history of diabetes, *n* (%)	90 (33.8)	94 (36.4)	0.533
DKA, *n* (%)	113 (37.8)	166 (52.2)	**<0.001**
Severe DKA, *n* (%)	33 (29.2)	60 (36.1)	0.227

Note: Bold values indicate the significant *p*values i.e., less or equal to 0.05.

Abbreviations: AOR, adjusted odds ratio; BMI: body mass index; 95% CI, 95% confidence interval; DKA, diabetic ketoacidosis; HbA1C, Haemoglobin A1C; IQR, interquartile range; PICU, paediatric intensive care unit; T1D, type 1 diabetes.

[a]Defined from 24 February 2020 to 23 February 2021.

[b]Defined from 24 February 2019 to 23 February 2020.

0 = no) as main outcome variables (Table 2). Furthermore, multiple logistic regression was used to explore the association between baseline characteristics and DKA, severe DKA, and PICU admission during the pandemic versus the pre-pandemic period (Table 3). This analysis was exploratory and guided by clinical judgement and the literature.[15,16]

The study was approved by the Standing committee for coordination of health and medical research at the MOH (#1569/2020). The study was performed in accord with the Declaration of Helsinki.

3 | RESULTS

A total of 324 children aged 6 months to 12 years were newly diagnosed with T1D during the first 12 months of the COVID-19 pandemic period in Kuwait (males, *n* = 151, 46.6% and females, *n* = 173, 53.4%), compared to a total of 303 children during 12 months of the pre-pandemic period. Baseline characteristics of newly diagnosed children with T1D during the COVID-19 pandemic period in comparison to the pre-pandemic period are shown in Table 2. No

TABLE 2 Adjusted odds ratio for DKA, severe DKA, and admission to PICU in children newly diagnosed with T1D during the study period[a]

	DKA			Severe DKA			PICU		
	AOR	95% CI	*p* value	AOR	95% CI	*p* value	AOR	95% CI	*p* value
COVID-19 period[a]	1.73	1.13–2.65	**0.012**	1.72	0.89–3.35	0.109	2.04	1.13–3.67	**0.018**
Age, years	0.97	0.90–1.00	0.336	1.08	0.97–1.19	0.165	0.90	0.82–0.99	**0.034**
Sex, male	0.78	0.51–1.20	0.258	0.94	0.48–1.83	0.858	1.05	0.58–1.89	0.872
BMI, z-scores	0.93	0.83–1.00	0.230	1.04	0.88–1.24	0.630	1.03	0.88–1.20	0.718
Family history of diabetes	0.34	0.22–0.54	**<0.001**	1.08	0.51–2.30	0.845	0.29	0.14–0.61	**0.001**

Note: Bold values indicate the significant *p* values i.e., less or equal to 0.05.

Abbreviations: AOR, adjusted odds ratio; BMI: body mass index; 95% CI, 95% confidence interval; DKA, diabetic ketoacidosis; PICU, paediatric intensive care unit; T1D, type 1 diabetes.

[a]Defined from 24 February 2020 to 23 February 2021.

TABLE 3 Adjusted odds ratio for DKA, severe DKA and admission to PICU in children newly diagnosed with T1D during the COVID-19 pandemic period[a] versus the pre-pandemic period[b]

	DKA			Severe DKA			PICU		
	AOR	95% CI	*p* value	AOR	95% CI	*p* value	AOR	95% CI	*p* value
COVID-19 pandemic									
Age, years	0.95	0.86–1.05	0.324	1.03	0.90–1.20	0.636	0.88	0.68–1.00	0.059
Sex, male	0.56	0.30–1.07	0.079	0.70	0.28–1.72	0.435	0.66	0.29–1.52	0.33
BMI, z-scores	0.88	0.74–1.04	0.143	0.95	0.78–1.18	0.680	0.99	0.81–1.22	0.942
Family history of diabetes	0.38	0.20–0.74	**0.004**	1.30	0.48–3.33	0.631	0.22	0.08–0.61	**0.004**
Pre-pandemic									
Age, years	0.98	0.88–1.08	0.662	1.14	0.96–1.36	0.143	0.92	0.79–1.06	0.249
Sex, male	1.06	0.60–1.88	0.847	1.31	0.47–3.64	0.600	1.82	0.76–4.39	0.181
BMI, z-scores	0.98	0.84–1.15	0.831	1.21	0.88–1.65	0.239	1.12	0.87–1.45	0.372
Family history of diabetes	0.31	0.16–0.59	**<0.001**	0.81	0.23–2.93	0.751	0.43	0.15–1.24	0.120

Note: Bold values indicate the significant *p* values i.e., less or equal to 0.05.

Abbreviations: AOR, adjusted odds ratio; BMI: body mass index; 95% CI, 95% confidence interval; DKA, diabetic ketoacidosis; PICU, paediatric intensive care unit; T1D, type 1 diabetes.

[a]Defined from 24 February 2020 to 23 February 2021.

[b]Defined from 24 February 2019 to 23 February 2020.

statistically significant differences between Kuwaiti and non-Kuwaiti children were observed in any of the characteristics evaluated and therefore, the entire group is presented as one data set.

The IR of T1D was 40.2 per 100,000 (95% CI; 36.0–44.8) during the COVID-19 pandemic period and was not statistically different from 37.6 per 100,000 (95% CI; 33.6–42.1) during the pre-pandemic period ($p = 0.4$). However, during the COVID-19 pandemic, there was an increase in the number of children newly diagnosed with T1D when evaluated by 3-month intervals (quarters) up until the interval of August to November 2020 (Figure 1; $p < 0.001$). However, in the last quarter of the COVID-19 pandemic period evaluated in this study, there was a decrease in the number of children newly diagnosed with T1D. In comparison, during the pre-pandemic period, there was no significant change in the incidence of T1D among children between the four quarters (Figure 1; $p = 0.19$). HbA1C, BMI z-scores, admission to PICU, presentation with DKA, and severity of DKA were not significantly different between the four quarters during of the COVID-19 pandemic.

Children newly diagnosed with T1D during the COVID-19 pandemic period presented with a slightly higher HbA1C than those diagnosed pre-pandemic (median HbA1C 11.8% (IQR 10.4–13.0) and 11.5% (IQR 9.9–12.6) respectively; $p = 0.019$). Furthermore, a higher proportion of newly diagnosed T1D cases presented with DKA and were admitted to the PICU during the pandemic period compared to those diagnosed during the pre-pandemic period (52.2% vs. 37.8%: $p < 0.001$, 19.8% vs. 10.9%; $p = 0.002$, respectively) (Table 1).

After adjusting for age, gender, BMI z-score and family history of diabetes, the COVID-19 pandemic period was positively associated with presentation of DKA and admission to PICU at the time of diagnosis of T1D (AOR = 1.73; 95% CI, 1.13–2.65; $p = 0.012$,

AOR = 2.04; 95% CI, 1.13–3.67; $p = 0.018$ respectively) (Table 2). When the analysis was repeated with severe DKA as an outcome variable, the COVID-19 pandemic period was not associated with severe DKA. Table 3 shows the baseline characteristics associated with DKA, severe DKA, and admission to the PICU during and before the COVID-19 pandemic period using logistic regression. Children of families with a positive history for diabetes were less likely to present with DKA or get admitted to the PICU during the COVID-19 pandemic compared to children of families without a positive family history of diabetes (AOR = 0.38; 95% CI, 0.20–0.74; $p = 0.004$, AOR = 0.22; 95% CI, 0.08–0.61; $p = 0.004$, respectively). During the pre-pandemic period, children of families with positive history of diabetes were less likely to present with DKA as well (AOR = 0.31; 95% CI, 0.16–0.59; $p < 0.001$). Although not statistically significant ($p = 0.059$), age was slightly inversely associated with admission to the PICU during the COVID-19 pandemic period (AOR = 0.88; 95% CI, 0.68–1.00).

4 | DISCUSSION

In this study compared children newly diagnosed with T1D for 12 months during the COVID-19 pandemic to their counterparts diagnosed in the 12 months prior to the pandemic using data from a validated national surveillance system in Kuwait.[11,12] We did not find any evidence for an increase in T1D incidence among children during the pandemic period. However, children diagnosed with T1D during the pandemic were more likely to present with DKA and get admitted to the PICU. Family history of diabetes was found to reduce the risk of presentation with DKA and admission to the PICU during the COVID-19 pandemic period.

Results of our study found no evidence for higher incidence of T1D among children during the pandemic period compared to the pre-pandemic period. Similarly, a report from Germany based on a shorter period of analysis (March to May 2020) found no short-term effect of the COVID-19 pandemic on T1D incidence in children.[17] However, a multicentre regional study from the United Kingdom reported that from March to June 2020, there was an apparent increase in children newly diagnosed with T1D in two regional units with 10 cases each compared to two and four cases, respectively, during the same period in the previous 5 years.[18] These reports compared data over a shorter duration of time, and therefore may not represent true changes in incidence. Our results add further evidence that during the first 12 months of the COVID-19 pandemic the overall incidence of T1D did not significantly increase compared to previous years.

We also noted a trend indicating an accumulative increase in the number of children diagnosed with T1D as the pandemic continued during the first three 3-month intervals (quarters) of the study period followed by a decrease in the last quarter. Such trends might be corresponding to the overall COVID-19 case-load in the country among all age groups (Information on COVID-19 status in Kuwait obtained from https://corona.e.gov.kw/en). Although this observation is speculative, however it raises questions about potential multifaceted connections between incident T1D and COVID-19. Unfortunately, any direct connection between COVID-19 infection and onset of T1D could not be evaluated in the present study as COVID-19 testing was not available nor done for all newly diagnosed children with T1D during the pandemic. While we found an accumulative increase in the incidence of T1D in the first three quarters during the COVID-19 pandemic, we did not find any significant differences between quarters with regard to HbA1C, BMI a-scores, presentation with DKA and its severity, or admission to PICU.

Results of our study found that children diagnosed with T1D during the pandemic were more likely to present with DKA and get admitted to the PICU. Previous reports from Kuwait have highlighted relatively high rates of DKA at the time of T1D diagnosis. For example, 37.7% of children presented with DKA between 2011 and 2013[16] and 37.8% during the immediate pre-pandemic period in the present study. During the COVID-19 pandemic period, the rate of DKA at diagnosis was substantially higher than all previous reports, 52.2%. There have been several studies reporting an increase in the overall presentation with DKA, especially severe DKA, during the COVID-19 pandemic.[18–22] The possible causes are likely multifactorial, reflecting unknown biological factors as well as delays in seeking medical care due to limited access to health care, fear of seeking medical attention due to the risk of infection and lack of recognition of DKA symptoms during periods of high stress.[19] However, it should be noted that in Kuwait access to emergency medical care has not been compromised during the COVID-19 pandemic, and a majority of the population lives in districts where medical services remained readily available. This might explain the unchanged rate of severe DKA in the country during the pandemic period. It is clearly of concern that serious health problems such as undiagnosed T1D and DKA might remain undiagnosed in times of limited interaction between patients and healthcare facilities.[23] DKA is a serious life-threating complication and might require the use of intensive care resources when severe, and therefore is an issue that should be urgently addressed. Special attention is clearly needed to be given to DKA in children newly diagnosed with T1D during the pandemic as it is linked to higher risk of morbidity and mortality as well as associated with increased healthcare expenditure[24] during a time of need of all possible resources to be directed towards fighting the pandemic.

A multicentre study from the Kingdom of Saudi Arabia found that children newly diagnosed with T1D during the pandemic (from March to June 2020) presented with higher HbA1C (10.87% in 2019 vs. 12.14% in 2020; $p < 0.001$).[21] In our study, HbA1C during a 12-month period of the pandemic was slightly higher compared to the pre-pandemic period (11.8% vs. 11.5%; $p = 0.019$). This was statistically significant, however, clinically of only minor importance. Furthermore, there was no significant change in HbA1C between the different quarters of the COVID-19 period.

Family history of diabetes was associated with lower risk of presentation with DKA and admission to the PICU during the COVID-19 pandemic. In earlier studies as well as our analysis of the pre-pandemic period showed that family history of diabetes was associated with lower risk of DKA at the time of diagnosis.[15,16] This

observation has also been made in our study as children from families with a history of diabetes were less likely to present with DKA and get admitted to the PICU during the COVID-19 pandemic period. This might be attributed to high awareness of early signs of the disease in families with previous experience with diabetes. Age at diagnosis of T1D was not associated with presentation with DKA or severe DKA during the pandemic. However, age was slightly negatively associated with admission to the PICU during the pandemic ($p = 0.059$). This might reflect a lowering of clinical threshold to admit younger children newly diagnosed with T1D to the PICU during a time of the pandemic as an extra precaution. This might also explain the higher rate of admission to the PICU during the pandemic when the rate of severe DKA was not different.

To the best of our knowledge, it is the first in the Middle East region and one of the first internationally to report on a longer period of the COVID-19 pandemic (12 months). Additionally, our data are from a validated nation-wide surveillance system (8). Limitations of our study include lack of data on socioeconomic status and residual β-cell function (c-peptide levels) which might confound the results and influence DKA and its severity. Furthermore, lack of data on COVID-19 status on children at the time of diagnosis which limits further study on direct impact of the infection on newly diagnosed T1D in children.

In conclusion, very high rates of DKA at presentation and admission to PICU in children newly diagnosed with T1D during the COVID-19 pandemic warrant further studies and effective mitigation efforts through increasing awareness, early detection, and timely intervention that need to be prioritised.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Azza Al Shaltout for founding and establishing the CODeR project. The authors would like to acknowledge all who had previously supported and worked in the CODeR project including; Dr Mona Al-Khawari, Dr Huda Al-Ghareeb, Dr Yasmin Khuraibit, Dr Wafeek Saba, Dr Mohammed Al-Otaibi, Dr Sharifa Al-Jassar, Dr Hossam Soror, Dr Esra Marafi, Dr Zaidan Al-Mazidi, Dr Nada Al-Turkait, Dr Fahad Al-Enzi, Dr Ahmad Al-Dosari, Dr Ammar Al-Mansour, Dr Nazila Al-Zanati, Dr Taha Darweesh, Dr Mariam Al-Rashed, Dr Thaer Al-Muaili, Dr Nabela Abdella, Dr Majedah Abdulrasoul, Dr Eba Al-Ozairi, Dr Mona Orekat, and Dr Abdel-Nabi Al-Attar. The authors are grateful for the research assistants at DDI for their efforts on this study; Mrs Sarah Qabazard, Miss Taiba al-Qaisi, Miss Fouzeyah Othman, and Miss Fatemah Al-Julaila. The authors further acknowledge Dr Abdulla Al-Taiar and Dr Lena Davidsson for their scientific review of this manuscript. We further express our gratitude to the study patients and their families and to all the dedicated nurses and diabetes educators involved in this project. This project has been funded by Dasman Diabetes Institute (DDI) (RA 2011-006).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

ETHICS STATEMENT

The study was approved by the Standing committee for coordination of health and medical research at the Ministry of Health of Kuwait (MOH) (#1569/2020).

The study was performed in accord with the Declaration of Helsinki.

The data used in this study was completely anonymised without any possibility to re-identify subjects.

A waiver of consent was granted by the Standing committee for coordination of health and medical research at the MOH.

AUTHOR CONTRIBUTIONS

All authors have contributed significantly to this manuscript and in keeping with the latest guidelines of the International Committee of Medical Journal Editors. Authors contributions were as follows: Dalia Al-Abdulrazzaq was principal investigator of this project, she was responsible for the conception, planning, data management and analysis, and conducting the study. She had drafted this manuscript. Abdullah Alkandari was responsible for the data analysis. Fatemah Alhusaini and Naser Alenazi were responsible for data collection and data management. Hessa Al-Kandari had participated in the planning, data management, and conducting the study. Unjali P. Gujral and K. M. Venkat Narayan had participated in writing the manuscript. All co-authors had participated in reviewing the manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the MOH and DDI but restrictions apply to the availability of these data, which were used under licence for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the MOH and DDI.

ORCID

Dalia Al-Abdulrazzaq https://orcid.org/0000-0002-4613-865X
K. M. Venkat Narayan https://orcid.org/0000-0001-8621-5405

TRANSPARENT PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/dmrr.3506.

REFERENCES

1. Seow CJ, Koh AWC, Lian JX, Dalan R, Boehm BO. Non autoimmune type 1B diabetes after mild COVID-19: report of three cases. *Diabetes Metab Res Rev*. 2021;37(5):e3438.
2. Maddaloni E, Buzzetti R. Covid-19 and diabetes mellitus: unveiling the interaction of two pandemics. *Diabetes Metab Res Rev*. 2020;36(7):e33213321.
3. Sharif K, Watad A, Coplan L, Amital H, Shoenfeld Y, Afek A. Psychological stress and type 1 diabetes mellitus: what is the link? *Expert Rev Clin Immunol*. 2018;14(12):1081-1088.
4. Caruso I, Molfetta SD, Guarini F, et al. Reduction of hypoglycaemia, lifestyle modifications and psychological distress during lockdown following SARS-CoV-2 outbreak in type 1 diabetes. *Diabetes Metab Res Rev*. 2021;37(6):e3404.

5. Maddaloni E, Coraggio L, Pieralice S, Carlone A, Pozzilli P, Buzzetti R. Effects of COVID-19 lockdown on glucose control: continuous glucose monitoring data from people with diabetes on intensive insulin therapy. *Diabetes Care*. 2020;43(8):e86-e87.
6. Silverii GA, Poggi CD, Dicembrini I, Monami M, Mannucci E. Glucose control in diabetes during home confinement for the first pandemic wave of COVID-19: a meta-analysis of observational studies. *Acta Diabetol*. Published online August 20, 2021. doi:10.1007/s00592-021-01754-2
7. Ludwig L, Scheyer N, Remen T, Guerci B. The impact of COVID-19 lockdown on metabolic control and access to healthcare in people with diabetes: the CONFI-DIAB cross-sectional study. *Diabetes Ther* 2021;12(8):2207-2221.
8. Dayal D, Gupta S, Raithatha D, Jayashree M. Missing during COVID-19 lockdown: children with onset of type 1 diabetes. *Acta Paediatr* 2020.
9. Maahs DM, Hermann JM, Holman N, et al. Rates of diabetic ketoacidosis: international comparison with 49,859 pediatric patients with type 1 diabetes from England, Wales, the U.S., Austria, and Germany. *Diabetes Care*. 2015;38(10):1876-1882.
10. Wolfsdorf JI, Glaser N, Agus M, et al. ISPAD clinical practice consensus guidelines 2018: diabetic ketoacidosis and the hyperglycemic hyperosmolar state. *Pediatr Diabetes*. 2018;19(Suppl 27):155-177.
11. Shaltout AA, Wake D, Thanaraj TA, et al. Incidence of type 1 diabetes has doubled in Kuwaiti children 0-14 years over the last 20 years. *Pediatr Diabetes*. 2017;18(8):761-766.
12. Al-Kandari H, Al-Abdulrazzaq D, Davidsson L, et al. Incidence of type 2 diabetes in Kuwaiti children and adolescents: results from the childhood-onset diabetes electronic registry (CODeR). *Front Endocrinol*. 2019;10:836.
13. Group W.H.O.M.G.R.S. WHO child growth standards based on length/height, weight and age. *Acta Paediatr Suppl*. 2006;450:76-85.
14. Mayer-Davis EJ, Kahkoska AR, Jefferies C, et al. ISPAD clinical practice consensus guidelines 2018: definition, epidemiology, and classification of diabetes in children and adolescents. *Pediatr Diabetes*. 2018;19(Suppl 27):7-19.
15. Usher-Smith JA, Thompson M, Ercole A, Walter FM. Variation between countries in the frequency of diabetic ketoacidosis at first presentation of type 1 diabetes in children: a systematic review. *Diabetologia*. 2012;55(11):2878-2894.
16. Shaltout AA, Channanath AM, Thanaraj TA, et al. Ketoacidosis at first presentation of type 1 diabetes mellitus among children: a study from Kuwait. *Sci Rep*. 2016;6:27519.
17. Tittel SR, Rosenbauer J, Kamrath C, et al. Did the COVID-19 lockdown affect the incidence of pediatric type 1 diabetes in Germany? *Diabetes Care*. 2020;43(11):e172-e173.
18. Unsworth R, Wallace S, Oliver NS, et al. New-onset type 1 diabetes in children during COVID-19: multicenter regional findings in the U. K. *Diabetes Care*. 2020;43(11):e170-e171.
19. Kamrath C, Mönkemöller K, Biester T, et al. Ketoacidosis in children and adolescents with newly diagnosed type 1 diabetes during the COVID-19 pandemic in Germany. *J Am Med Assoc*. 2020;324(8):801-804.
20. Beliard K, Demeterco-Berggren C, Alonso GT, Gallagher MP, Clements M, Rapaport R. Increased DKA at presentation among newly diagnosed type 1 diabetes patients with or without COVID-19: data from a multi-site surveillance registry. *J Diabetes*. 2020;13(3):270–272. doi:10.1111/1753-0407
21. Alaqeel A, Aljuraibah F, Alsuhaibani M, et al. The impact of COVID-19 pandemic lockdown on the incidence of new-onset type 1 diabetes and ketoacidosis among Saudi children. *Front Endocrinol*. 2021;12:669302.
22. Lawrence C, Seckold R, Smart C, et al. Increased paediatric presentations of severe diabetic ketoacidosis in an Australian tertiary centre during the COVID-19 pandemic. *Diabet Med*. 2021;38(1):e14417.
23. Lazzerini M, Barbi E, Apicella A, Marchetti F, Cardinale F, Trobia G. Delayed access or provision of care in Italy resulting from fear of COVID-19. *Lancet Child Adolesc Health*. 2020;4(5):e10-e11.
24. Shrestha SS, Zhang P, Barker L, Imperatore G. Medical expenditures associated with diabetes acute complications in privately insured U. S. youth. *Diabetes Care*. 2010;33(12):2617-2622.

How to cite this article: Al-Abdulrazzaq D, Alkandari A, Alhusaini F, et al. Higher rates of diabetic ketoacidosis and admission to the paediatric intensive care unit among newly diagnosed children with type 1 diabetes in Kuwait during the COVID-19 pandemic. *Diabetes Metab Res Rev*. 2022;38(3):e3506. https://doi.org/10.1002/dmrr.3506