Coronavirus disease 2019 (COVID-19) pandemic is a worldwide public health emergency. Children seem less likely to be infected with COVID-19 and develop milder symptoms than adults if infected. However, there is limited data regarding the impact of COVID-19 pandemic on diabetic children.

Objective: This systematic review aims to summarize and compile the available evidence of COVID-19 pandemic on the pediatric diabetic population, including the incidence of newly diagnosed patients, the risk of DKA and disturbed glycemic control, the use of telemedicine, the impact of lockdown on the daily dietary and physical activity routine, and the management of diabetes during the pandemic.

Method: We conducted a comprehensive search of literature published in PubMed, Google Scholar, and Cochrane databases for studies published in English language within the last year as of October 1st, 2020 on the impact of COVID-19 pandemic on diabetic children.

Results: We included 20 studies (7 incidence studies, 5 cross sectional, 2 observational, 4 case reports and 2 case series) with a total population of 1989 diabetic children and adolescents. The current evidence suggesting increased incidence of newly diagnosed type 1 diabetes (T1DM) during the COVID-19 pandemic is still weak. Several studies identified delayed diagnosis of children and adolescents with new-onset T1DM leading to presentation with severe DKA. Underlying causes contributed to this observation include reduced access to primary care services, limited availability of healthcare providers, and parental fear from infection during the pandemic period. Moreover, the current pandemic affected the availability of Insulin and glucose measuring supplies leading to poor glycemic control and increasing the risk of DKA among diabetic children especially in resource limited countries. Diabetic children and adolescents had shown good coping skills as a considerable number of them maintained their eating habits and regularly practiced physical activity at home during the lockdown period. In addition, the results of studies on the use of telemedicine for diabetic children and adolescents were positive regarding the effectiveness and patient satisfaction.

Conclusion: More studies are required to document the association between COVID-19 infection and the development of T1DM, and to evaluate the physical and psychological impact of the current pandemic on diabetic children and adolescents. In preparation for any potential second wave, specific strategies are essential to alleviate the negative impact of the current pandemic on the management of diabetic children. In order to avoid delayed diagnosis of patients with new onset diabetes, countries should reopen the access to essential non-COVID-19 services, and families should be encouraged about timely attendance at the ED for children with symptoms that are not related to COVID-19. Telemedicine is a promising approach for the management of diabetic patients as it provides a safe, fast and effective way of communication between patients and their diabetic teams.
Keywords: adolescents; children; COVID-19; diabetes mellitus and DKA; pediatrics; SARSCoV2

Introduction

Coronavirus disease 2019 (COVID-19) pandemic is a worldwide public health emergency. The World Health Organization declared the outbreak as a pandemic on March 11th, 2020. In general, it can be hypothesized that children are less likely to be infected with COVID-19 and those that are infected develop milder symptom [1]. The incidence and prevalence of both Type 1 diabetes mellitus (T1DM) and Type 2 diabetes mellitus is increasing around the world [2]. There is currently no evidence suggesting a higher risk of COVID-19 infection among children with diabetes than non-diabetics [3]. Diabetic patients have an increased risk of infection by bacterial, viral, and fungal agents due to hyperglycemia induced immune dysfunction through neutrophil and humoral immunity damage, antioxidant system depression, and micro-and macro-angiopathies [4, 5]. Moreover, the current pandemic has put children with new non-COVID-19 illnesses at risk of delayed diagnosis and higher risk for complications and even mortality. This is mainly because of restricted access to health care services or parental fear and anxiety to catch COVID-19 infection through contact with the health system. Children with onset of type 1 diabetes may progress rapidly to diabetic ketoacidosis if diagnosis is missed or delayed with increasing risk of severe morbidity and mortality. Therefore, there are rising concerns from experts on missing diagnoses and deaths for diabetic children in resource-limited countries [6]. In addition, COVID-19 has significantly impacted the daily lives of individuals living with diabetes through financial consequences, medication and glucose monitoring supplies availability, the dietary and physical activity routine besides its psychological burden [7].

Objective

There is limited data regarding the impact of SARSCoV2 infection in diabetic children. This systematic review aims to summarize and compile the available evidence of COVID-19 pandemic on the pediatric diabetic population, including the incidence of newly diagnosed patients, the risk of DKA and disturbed glycemic control, the use of telemedicine, the impact of lockdown on the daily dietary and physical activity routine, and the management of diabetes during the pandemic.

Methods

We performed a systematic review of the literature following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to gain insight into the impact of COVID-19 on diabetic children (Figure 1). We searched PubMed MEDLINE/PubMed (http://www.ncbi.nlm.nih.gov/pubmed/), Google Scholar, and Cochrane databases for studies published until October 1st, 2020, with a focus on COVID-19, SARSCoV2, diabetes, children, adolescents, and DKA. We also reviewed the references within the included articles. We identified 187 articles from database search and additional 6 articles during the hand search of the bibliography.

After removing duplicate publications 179 articles underwent title and abstract review from which 36 articles were selected for full text review. Two independent authors performed data extraction, with disagreement resolved by consensus. A standardized data extraction form was developed to collect information from the screened studies which included: time of publication, the country where the study was performed, the number of patients, baseline characteristics (average age or sex proportion), study design or type of study and outcomes assessed. In this review we included 20 articles which fulfilled our inclusion criteria. Our inclusion criteria were: studies reported in English language, done on children and adolescents up to 20 years of age with new onset or prior diagnosis of diabetes mellitus, and research study design including: epidemiological, observational, cross sectional studies, case reports or case series. A total number of 16 studies fulfilled exclusion criteria and were removed from the review. Exclusion criteria included: studies done on the adult population (more than 50% of the included individuals) or on children without diabetes, narratives, scoping reviews, editorials, recommendations, and guidelines. The table of excluded studies after full text review is provided in (Appendix 1).
Results and Discussion

We included 20 relevant articles (Table 1), each carried part of the evidence regarding the impact of COVID-19 on diabetic children, the incidence of newly diagnosed patients, the risk of DKA and glycemic control, the use of telemedicine, the impact of lockdown on the daily dietary and physical activity routine, and the management of diabetes during the pandemic. None of the included studies was RCT, but we identified 7 incidence studies, 2 observational, 5 cross sectional, 4 case reports and 2 case series with a total population number of 1989 children and adolescents.

<table>
<thead>
<tr>
<th>Author/Country</th>
<th>Population</th>
<th>Findings</th>
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<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Age/sex</td>
</tr>
<tr>
<td><strong>Incidence studies:</strong></td>
<td></td>
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<tr>
<td><strong>Unsworth et al., 2020 [8]</strong></td>
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<tr>
<td>UK</td>
<td>30 newly diagnosed T1DM</td>
<td>Age range 23 months-16.8 years</td>
</tr>
<tr>
<td><strong>Tittel et al., 2020 [9]</strong></td>
<td>532</td>
<td>Age range 6 months-18 years</td>
</tr>
<tr>
<td>Citation</td>
<td>Observational studies:</td>
<td></td>
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<tr>
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<tr>
<td>Basatemur et al., 2020 [10]</td>
<td><strong>UK</strong></td>
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<tr>
<td>31 newly diagnosed T1DM</td>
<td>There was a significant increase in referral of children with confirmed diagnosis of DKA during the COVID-19 pandemic between March and July 2020 (31 cases) compared with the same period during previous 5 years (a median of 12 cases), at a time when overall referral rate to the service was lower than usual. Moreover, there were no significant differences in the severity of DKA, duration of symptoms before hospital attendance, blood gas finding at presentation, ICU admission or intubation rates between cases referred before and during the pandemic.</td>
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<tr>
<td>Atlas et al., 2020 (11)</td>
<td><strong>Australia</strong></td>
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<tr>
<td>58 newly diagnosed T1DM</td>
<td>Data collected from 2 hospitals in Melbourne. The number of new cases of T1DM between February and May in 2020 was similar to the previous years from 2017 to 2019. Moreover, DKA rate, DKA severity and ICU admissions were similar for all years. None of the included individuals had COVID-19 infection.</td>
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<tr>
<td>Kamrath et al., 2020 [12]</td>
<td><strong>Germany</strong></td>
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<tr>
<td>532 newly diagnosed T1DM</td>
<td>This study used diabetes registry data to compare the frequency of DKA in children and adolescents with new T1DM diagnosis in Germany from March 13 to May 13 in 2020 versus the same time period in 2018 and 2019. It was found that the incidence of DKA was significantly higher during the COVID-19 pandemic compared to the previous years (44.7% in 2020 vs. 24.5% in 2019; vs. 24.1% in 2018). Also, the incidence of severe DKA was significantly higher during the COVID-19 pandemic (19.4% in 2020 vs. 13.9% in 2019; vs. 12.3% in 2018).</td>
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<tr>
<td>Rabbone et al., 2020 [13]</td>
<td><strong>Italy</strong></td>
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<tr>
<td>160 with T1DM</td>
<td>This study is a Web-based survey including all Italian pediatric diabetes centers to collect diabetes, DKA, and COVID-19 data in patients with new-onset or established T1DM in the period from 20 February to 14 April in 2019 and 2020. The study reported reduction in new diabetes cases in 2020 by 23% compared with 2019. While there was a significant increase in the proportion of newly diagnosed diabetics with severe DKA (44.3% in 2020 vs. 36.1% in 2019 (P= 0.03).</td>
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<tr>
<td>Dayal et al., 2020 a [6]</td>
<td><strong>India</strong></td>
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<tr>
<td>3 with new onset T1DM</td>
<td>This study was done in a tertiary care pediatric referral hospital in India. There was a major reduction in hospitalization rate of children with onset of T1DM during April 2020 (3 vs. 12 per month; reduction 75%). Also, the proportion of presentations in severe DKA increased. All three admissions with onset of type 1 diabetes in April 2020 were with severe DKA as compared to only 15% (average 2 out of 12/month) during the previous 12 months because of delayed diagnosis.</td>
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<tr>
<td>Christoforidis et al., 2020 (14)</td>
<td><strong>Greece</strong></td>
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<tr>
<td>34 with T1DM</td>
<td>Included children used Mon Medtronic 640G insulin pump equipped with the Enlite Sensor uploaded by Care Link. Data were categorized in 2 three-week periods before and after the 10th of March. Interestingly, the glucose variability was more during the pre-lockdown period. There was no significant change in the total daily insulin dose nor the carbohydrate consumption. The lockdown dramatically affected the meal timing as the percentage of breakfast consumption before 10.00 a.m. significantly fell from 80.67% to 41.46% (p &lt; 0.001) and, the percentage of dinner consumption before 10.00 p.m. Has fallen from 60.22% to 53.78% (p = 0.019) during the lockdown.</td>
<td></td>
</tr>
<tr>
<td>Study Authors and Country</td>
<td>Study Design</td>
<td>Participants</td>
</tr>
<tr>
<td>---------------------------</td>
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<tr>
<td>Tornese et al., 2020 [15] Italy</td>
<td>Retrospective study</td>
<td>13 with T1DM</td>
</tr>
<tr>
<td>Odeh et al., 2020 [16] Jordan</td>
<td>Cross-sectional studies</td>
<td>235 patients/families T1DM</td>
</tr>
<tr>
<td>Ebekozien et al., 2020 [17] USA</td>
<td>This study used the Qualtrics survey tool with a 33-item questionnaire. It was found that the most common presenting symptoms was hypoglycemia which was reported in 50% of all reported cases and nearly one-third of patients experienced DKA.</td>
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<tr>
<td>Verma et al., 2020 [18] India</td>
<td>This study is a questionnaire-based on patients with T1DM which reported that about 36.5% had hyperglycemic and 15.3% had hypoglycemic episodes. Insulin dose was missed in 26.9%, glucose monitoring not done routinely in 36.5%. Glycemic control was worse during the lockdown period as the average blood glucose increased from 212.3 ± 57.9 mg/dl lockdown phase to 276.9 ± 64.7 mg/dl during the lockdown period. Also, mean HbA1c value increased from (8.8 ± 1.3%) to (10 ± 1.5%) during the lockdown, that increase was statistically significant (p &lt; 0.05).</td>
<td>52 with T1DM</td>
</tr>
</tbody>
</table>
Passanisi et al., 2020 [1]
Italy
204 with T1DM
Age range 5-18 by male gender (57.8%)
This study used a web-based survey and reported that the lock-down period affected more the younger (≤12 yrs of age) than older patients. More than half of individuals (56.9%) did not change their dietary habits during the quarantine period. While 26.5%, 7.8% and 8.8% consumed large amounts of carbohydrates, fat, and protein, respectively. Regarding physical activity, 20.6% of patients spent 4 hours/week on physical activity, 27.9% had 1-3 hours/week and 17.7% of patients had less than 1 hour of physical activity weekly. Moreover, 47.5% of subjects did not change their daily glucose monitoring routine while 33.8% had more frequent monitoring during the lock-down period.

Lim et al., 2020 [19]
Singapore
14 adolescents and 6 parents
13-20 years
This is a questionnaire-based study adolescents with T1DM and with T2DM on oral hypoglycemic agents with or without insulin. It was found that 63% of the participants were very satisfied by the administrative process of telehealth service. About 70% satisfied by many aspects of the service especially the duration of consultation and the ability to ask questions and get satisfactory answers. As regard the comparison between telehealth services and in person clinic visits, 80% of participants reported it was similar and 20% reported telehealth services to be even better than in person visits. More than 65% of the participants are willing to continue using the telehealth service in the future. Telemedicine service has the advantage of reducing the anxiety of getting infected by COVID-19. Patients diabetic control was appropriate as no recorded ER visits related to diabetes complications of the included patients and HbA1c level was stable during follow up.

Case series:

Lazzerini et al., 2020 [20]
Italy
12
Below 18 years of age
All cases have been reported during the week of March 23–27, 2020 across five hospitals in Italy. All had delayed access to hospital care. Half of the children were admitted to an ICU and four died. Notably, no death occurred in the same hospitals during the same period in 2019. Delayed diagnosis was due to parental fear of acquiring COVID-19 infection during accessing health care service and unavailability of healthcare providers during that period. All cases either had a negative RT-PCR test for SARSCoV2 infection or didn’t have symptoms to justify the testing.

Cherubini et al., 2020 [21]
Italy
5
This case series describes cases of delayed diagnosis of diabetes leading to severe DKA; the first case is from California, a previously well 8-year-old boy presented to the ER with severe DKA following abdominal pain and vomiting for 5 days during which he had multiple contacts with medical providers. Another 3 cases presented with severe DKA (a pH of less than 6.8) in the first week after the national lockdown in Italy. The last case is an Indian 17-year-old girl presented to the ER with tachypnea, shortness of breath and cough and was diagnosed as severe DKA. She complained of polydipsia, polyuria and significant weight loss in the previous weeks.

Case reports:

Rabizadeh et al., 2020 [22]
Iran
1
16 y old boy
A 16-year-old teenage boy presented with severe DKA and COVID-19 infection as the first manifestation of his diabetes. He was admitted to ICU and managed for DKA (Intravenous fluids, regular insulin) and received treatment for COVID-19 (Hydroxychloroquine and Kaletra (lopinavir/ritonavir). He was discharged after 10 days of admission in a good condition.

Dayal et al., 2020 b [23]
India
1
2½ year old girl
A previously healthy girl presented to the ER in a critical condition on manual ventilation and was rapidly resuscitated for hemodynamic instability. She was diagnosed with severe DKA based on the initial blood glucose, 635 mg/dL, blood ketone, 4.8 mmol/L, blood pH of 6.9, and serum bicarbonate of 4.8 mmol/L. She was admitted to ICU for 5 days where she was mechanically ventilated, received inotropes and IV insulin infusion till stabilization then was transferred to the endocrine department for diabetes education.
USA

12 months old female

A 12 months old previously healthy female presented to the ER in moderate DKA, she had vomiting and lethargy for 2 days with a history of polyuria and polydipsia for 1-week. She was started on an insulin pump and continuous glucose monitoring during the first day of outpatient new-onset diabetes education. Telemedicine was used effectively and safely for ongoing diabetes education of the family. The family was educated how to upload the insulin pump data using their home computer. The physician was able to adjust the daily insulin dose via phone and/or e-mail.

Ireland

8 years old girl

A previously well female child presented to the ER in a critical condition (tachypneic, kussmaul breathing, severe dehydration and prolonged capillary refill time). She had a 2 days history of vomiting, abdominal pain and headache preceded by 3 weeks of polyurea, polydipsia and significant weight loss. She had difficulty getting an appointment with a physician during the lockdown period. She was managed in the pediatric high dependency till full recovery.

Table 1: The characteristics of included studies:

<table>
<thead>
<tr>
<th>Name of the study</th>
<th>Author</th>
<th>Reason of exclusion</th>
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<tbody>
<tr>
<td>Caring for children and adolescents with type 1 diabetes mellitus: Italian Society for Pediatric Endocrinology and Diabetology (ISPED) statements during COVID-19 pandemic</td>
<td>d’Annunzio et al., 2020</td>
<td>Guidelines</td>
</tr>
<tr>
<td>Type 1 Diabetes and COVID-19: Preliminary Findings From a Multicenter Surveillance Study in the U.S</td>
<td>Ebekozien et al., 2020</td>
<td>Adult Population</td>
</tr>
<tr>
<td>School and pre-school children with type 1 diabetes during COVID-19 quarantine: The synergic effect of parental care and technology</td>
<td>Schiaffini et al., 2020</td>
<td>Not relevant to the scope of our study</td>
</tr>
<tr>
<td>Characteristics and Outcomes of Children With Coronavirus Disease 2019 (COVID-19) Infection Admitted to US and Canadian Pediatric Intensive Care Units</td>
<td>Shekerdemian et al., 2020</td>
<td>No diabetic Patients</td>
</tr>
<tr>
<td>Clinical Characteristics and Outcomes of Hospitalized and Critically Ill Children and Adolescents with Coronavirus Disease 2019 at a Tertiary Care Medical Center in New York City</td>
<td>Chao et al., 2020</td>
<td>No diabetic Patients</td>
</tr>
<tr>
<td>Epidemiology, Clinical Features, and Disease Severity in Patients with Coronavirus Disease 2019 (COVID-19) in a Children’s Hospital in New York City, NewYork</td>
<td>Zachariah et al., 2020</td>
<td>No specific comment on diabetics</td>
</tr>
<tr>
<td>The Epidemiology of Severe Acute Respiratory Syndrome Coronavirus 2 in a Pediatric Healthcare Network in the United States</td>
<td>Otto et al., 2020</td>
<td>No specific comment on diabetics</td>
</tr>
</tbody>
</table>

Coronavirus Disease 2019 in Children Cared for at Texas Children’s Hospital: Initial Clinical Characteristics and Outcomes: Foster et al., 2020, 2/57 had DKA

Impact of the COVID-19 pandemic on emergency department: Early findings from a hospital in Madrid: Gutiérrez et al., 2020, 4/530 pts discharged with DM related diagnosis

Clinical Manifestations and Outcomes of Critically Ill Children and Adolescents with Coronavirus Disease 2019 in New York City: Derespina et al., 2020, 9/70 had diabetes

Epidemiology and Clinical Presentation of Children Hospitalized with SARSCoV2 Infection in Suburbs of Paris: Gaborieau et al., 2020, Only 1/192 included population had diabetes

Delayed access to care and late presentations in children during the COVID-19 pandemic: a snapshot survey of 4075 paediatricians in the UK and Ireland: Lynn et al., 2020, The population was pediatrician

Severe Coronavirus Disease-2019 in Children and Young Adults in the Washington, DC, Metropolitan Region: DeBiasi et al., 2020, Only 5/177 of included patients had diabetes

Challenges in the Care of Children and Youth With Diabetes in Times of the Corona Pandemic: Personal View of the Situation in a German Clinic: Ziegler R. et al., Expert opinion

Caring for Pediatric Patients with Diabetes amidst the Coronavirus Disease 2019 Storm: Ho et al., 2020, Narrative study

### Appendix 1: Table of excluded studies after full text review

**COVID-19 pandemic and the Incidence of newly diagnosed diabetes**

Viral infections are well known to be associated with the development of T1DM in genetically predisposed individuals as they can trigger autoimmune destruction of pancreatic β-cell through several mechanisms. Coronaviruses were identified as one of the incriminating pathogens in the TEDDY study [26, 27]. Unsworth and others 2020 [8] reported an 80% increase in newly diagnosed patients with type 1 diabetes during the COVID-19 pandemic than a typical year in a multiregional study in the UK. It is possible that an increasing incidence of T1DM may be triggered by SARSCoV2 infection; but more appropriately designed studies are needed either to prove or rule out this possibility [28].

However, studies from Germany and Australia, reported that the incidence of newly diagnosed diabetes was not changed in 2020 compared to the previous year [9, 11]. While, Rabbone and others 2020 [13] found that there was a 23% reduction in new diabetes cases during the early phase of COVID-19 pandemic in Italy compared with 2019 and that significantly higher percent of those children presented in a state of severe DKA (44.3% in 2020 vs. 36.1% in 2019 (P= 0.03). Similar findings were reported by Dayal and others 2020 [6] who discovered a 75% reduction in admission rate of newly diagnosed children with diabetes during COVID-19 lockdown in India and a significant increase in the proportion of presentations by severe DKA. This could be explained by the fear of contracting COVID-19 in a hospital setting, restricted access to healthcare facilities during the quarantine period and closure of hospital services for non-COVID-19 related illnesses [28].
COVID-19 pandemic and delayed diagnosis of new cases with diabetes

The International Society for Pediatric and Adolescent Diabetes (ISPAD) received several reports about delayed hospitalization of patients with newly diagnosed T1DM or DKA episodes during COVID-19 pandemic [29]. Diabetic ketoacidosis is a medical emergency which needs to promote intervention and meticulous management. It is defined as a pH level less than 7.3 and/or bicarbonate level less than 15 mmol/L, while, in severe DKA blood pH level less than 7.1 and/or bicarbonate level less than 5 mmol/L [30, 31].

During review of the included studies, we identified several reports of delayed diagnosis of patients with new-onset T1DM leading to presentation with severe DKA. Lazzerini and others 2020 [20] from Italy reported 12 cases presented with severe DKA due to delayed access to hospital care, half of the reported children were admitted to ICU and one fourth (4 cases) died. This represents an increased rate of pediatric mortality during the COVID-19 pandemic compared to zero pediatric deaths in the same hospitals during 2019. Cherubini and others (21) reported a case series of 5 children with newly diagnosed diabetes (1 in USA, 1 in India and 3 in Italy) presented with severe DKA due to delayed diagnosis. Furthermore, similar cases were reported from India [23] and Ireland [25]. Basatemur and others 2020 [10], observed an increase in referral of children with DKA during the COVID-19 pandemic compared with previous years in UK (31 children between March and July 2020, compared with a median of 12 over corresponding months in the preceding 5 years), at a time when overall referral activity to the service was lower than usual. In agreement with the previous findings, Kamrath and others 2020 [12] reported a significant increase in DKA (44.7% in 2020 vs. 24.5% in 2019; vs. 24.1% in 2018) and severe DKA (19.4% in 2020 vs. 13.9% in 2019; vs. 12.3% in 2018) at diabetes diagnosis in children and adolescents during the COVID-19 pandemic in Germany. On the other hand, only one report from Australia found no difference between the expected rate of DKA or severe DKA in 2020 compared to previous years from 2017 to 2019 [11].

There are various causes of delayed presentation of new onset T1DM and increased risk for severe DKA: reduced access to health care services, limited availability of healthcare providers, and parental anxiety about risk of infection during the pandemic period [6]. Moreover, physicians are preoccupied with COVID-19 and might not consider DKA in the differential diagnosis because of the overlap of clinical features of DKA and viral illnesses in children. So, physicians are encouraged to look out for clinical feature of DKA (polyuria, polydipsia, weight loss, Kussmaul’s respiration, and a fruity odor in breath) and keep high index of suspicion whenever appropriate [28]. It is therefore important that all countries make suitable modifications to COVID-19 restrictions, re-open essential non-COVID services [23]. The public must be empowered to overcome ‘pandemic fear’ and parents should be encouraged to access medical care if they are concerned and must not delay seeking emergency medical consultation if their child appears seriously ill. Otherwise, the unintended consequences of the lockdown will do more harm and claim more children’s lives than COVID-19 [32].

Impact of COVID-19 pandemic on the management of diabetes

Since T1DM is known to be greatly affected by alterations in daily routine, there are concerns that lockdown can worsen glycemic control in T1DM due to shortage of insulin or glucose measuring equipment, restriction of outdoor physical activity, change in dietary routine, increased psychological stress and irregular sleep pattern [33, 34]. Moreover, contracting an illness might increase the risk of development of glycemic variability and DKA in diabetic patients. In accordance with this, Ebekozien and others 2020 [17], identified that the most common presenting symptoms and outcomes for 64 children with type 1 diabetes who have confirmed or suspected COVID-19 in the USA were hyperglycemia and DKA in 50% and 33% of patients respectively.

One of the main concerns during COVID-19 pandemic is supply chain disruptions leading to lack of availability of medication and glucose testing strips [35]. One study from India reported that insulin dose was missed in 26.9% and glucose monitoring not done routinely in 36.5% of studied patients leading to significant elevation of the average blood glucose and HbA1C during lockdown period compared to the pre lockdown period mainly due to non-availability of insulin/glucostrips during lockdown period [18]. In accordance with the previous study, Odeh and others 2020 from Jordan [16], did a cross sectional study on 235 patients/families with T1DM and found that 58.3% of families faced insulin shortages and glucose monitoring strips were rationed by 43.4% leading to more frequent episodes of hypo/hyperglycemia. Moreover, eight children (3.4%) were hospitalized due to acute metabolic complications and 1.7% had DKA. The direct Course of DKA mentioned by the families was non-adherence to insulin.

Interestingly, on the other hand, two studies from Greece [14] and Italy [15] reported that glycemic control was successfully maintained within the desirable level during the lockdown period and did not show significant variability from that of the pre-lockdown in children with T1DM using insulin pump equipped with sensor, which highlights the promising role of this new technology in management of childhood diabetes in the future. Since it is well established that uncontrolled hyperglycemia impairs immune function in diabetic patients, it would be logical to presume that achieving a tight glycemic control could serve as a means of primary prevention against acquiring infections. So, diabetic children are encouraged to keep a tight glycemic control especially during the current pandemic [36, 37].

Impact of lockdown on dietary habits and physical activity

There is a concern that forced sedentary behavior during the pandemic might negatively influence dietary habits, physical activity and hence the degree of glycemic control [38, 34]. Despite that, Passanisi and others 2020 [1] conducted a web based questionnaire to investigate the behavioral responses in a cohort of children and adolescents with T1DM during COVID-19 lockdown in Italy and found that that most of the individuals developed excellent resilience and coping skills as more than half of children maintained their eating habits and 63.3%...
regularly practiced physical activity at home and 47.5% of subjects did not change their daily glucose monitoring routine during the lockdown period. Moreover, Torneese and others 2020 [15], in their retrospective study in Italy found that the metabolic control of T1DM in adolescents did not worsen due to COVID-19 pandemics, and maintaining regular physical activity with routine exercise in a safe home environment improved the glycemic control among participants. Hence, people living with diabetes should be encouraged to do in-home physical activity (e.g., bodyweight exercise, jump rope, online lessons) as it can help improve glycemic control, reduces stress and anxiety and improves mood and sleep quality which is essential for their psychological well-being [39, 40].

**Telemedicine during COVID-19 pandemic**

In response to the restricted in person contact measures during the pandemic, several diabetes centers have developed and implemented telemedicine services. The aim of this is to allow proper communication between patients and the diabetic team and ensure optimum ongoing diabetes management [41]. Lately, there has been remarkable advancement in the use of universal digital platforms for continuous glucose monitoring, download, as well as connectivity to electronic medical records [3]. Digital technology can be used to connect patients with all members of the diabetic team: physicians, nurses, diabetes educators, dieticians, and psychologists to ensure coverage of all aspects of diabetic care [42].

Overall, the results of studies on the use of telemedicine for diabetic children and adolescents were promising regarding the effectiveness and patient satisfaction. In a nurse led telehealth initiative study in Singapore by Lim and others 2020 [19], reported that more than two thirds of the included adolescents felt very satisfied with the quality of telehealth service and are willing to continue using telehealth care service in the future. As regard the comparison between telehealth services and in person clinic visits, 80% of participants reported that it was similar and 20% reported telehealth services to be even better than in person visits because of spending less time in the hospital which reduced their anxiety around contracting COVID-19. In accordance with the previous findings, another study from Jordan found that most of the participants (85.5%) described the experience of communication with healthcare professionals via phones and social media applications as a smooth and positive experience [16]. Furthermore, Garg and others 2020 [24], concluded that telemedicine can be a safe and an effective approach for ongoing management and education of new onset T1DM patients and their families. Telemedicine could be integrated in the usual care of diabetic patients in the future as it provides a fast and safe communication channel between patients and the diabetic teams. However, there are several limitations including: the inability to perform a proper physical exam, obtaining accurate weight and vital signs measurements. The use of video can allow skin examination for injection site assessment and digital blood pressure measuring equipment can provide an alternative means for data collection [24].

**Conclusion**

More studies are required to document the association between COVID-19 infection and the development of T1DM, and to evaluate the physical and psychological impact of the current pandemic on diabetic children and adolescents. In preparation for any potential second wave, specific strategies are essential to alleviate the negative impact of the current pandemic on the management of diabetic children. In order to avoid delayed diagnosis of patients with new onset diabetes, countries should reopen the access to essential non-COVID-19 services, and families should be encouraged about timely attendance at the ED for children with symptoms that are not related to COVID-19. Telemedicine is a promising approach for the management of diabetic patients as it provides a safe, fast, and effective way of communication between patients and their diabetic teams.

**Conflict of interest:**

None

**References**

Ketoacidosis in Children and Adolescents With Newly Diagnosed Type 1 Diabetes During the COVID-19 Pandemic in Germany. JAMA 324: 801-804.


