Journal of Pediatric Nursing 81 (2025) 63–67

Contents lists available at ScienceDirect

Journal of Pediatric Nursing

journal homepage: www.pediatricnursing.org

The outcomes of implementing clinical guidelines to manage pediatric diabetic ketoacidosis in emergency department

Majdi Younis [a], Ahmad Ayed [b], Ahmad Batran [c], Mohammed A.L. Bashtawy [d], Yahya Najjar [e], Osama Alkouri [f], Aaliyah Momani [g], Abdulqadir J. Nashwan [h,*], Anas Ababneh [f]

[a] Rafidia Surgical Hospital, Palestinian Ministry of Health, Nablus, Palestine
[b] Faculty of Nursing, Arab American University, Jenin, Palestine
[c] Faculty of Allied Medical Sciences, Department of Nursing, Palestine Ahliya University, Bethlehem, Palestine
[d] Princess Salma Faculty of Nursing, Al al-Bayt University, Mafraq, Jordan
[e] Al-Balqa Applied University, Zarqa University College, Zarqa, Jordan
[f] Faculty of Nursing, Yarmouk University, Irbid, Jordan
[g] Faculty of Nursing, Applied Science Private University, Amman, Jordan
[h] Department of Nursing & Midwifery Research, Hamad Medical Corporation, Doha, Qatar

ARTICLE INFO

Article history:
Received 18 August 2024
Revised 13 January 2025
Accepted 13 January 2025
Available online xxxx

Keywords:
Diabetic ketoacidosis
Children
Diabetes mellitus type 1
Emergency
Guidelines

ABSTRACT

Background: Type 1 diabetes is the most common endocrine health condition among youth. Healthcare professionals must consider evidence-based guidelines in managing children and adolescents with diabetic ketoacidosis (DKA). The current study aims to assess the outcomes of implementing clinical guidelines by the American Diabetes Association to manage DKA among pediatrics in an emergency department in Palestine.

Methods: A prospective cohort study was conducted among 60 children (<12 years old) with type 1 diabetes mellitus with DKA throughout February to May 2021. The children were assessed on arrival and during the next 6 h for implementing the recommended guidelines of DKA management (e.g., fluids and insulin therapy). The assessment included measurement of vital signs (blood pressure, heart rate, respiratory rate, O_2 saturation), PH, HCO3-, and random blood glucose (RBG). A repeated-measure ANOVA was used to detect the difference between outcome measures during the follow-up period.

Results: After implementing the recommended guidelines of DKA management, all vital signs improved significantly in the follow-up period ($p < 0.05$). Also, PH, HCO_3-, and random blood glucose (RBG) were significantly enhanced in the follow-up period ($p < 0.05$) among children with DKA.

Conclusion: The study demonstrated that the recommended DKA management guidelines effectively managed children with DKA in emergency departments. Healthcare professionals should adhere to the guidelines when treating children with DKA.

Introduction

Type 1 Diabetes Mellitus (DM) is the most common form of diabetes among youth (Lawrence et al., 2021). Healthcare professionals must consider the unique aspects of caring for and managing children and adolescents with type 1 diabetes. These include changes in insulin sensitivity related to physical growth and sexual maturation, the ability to provide self-care, supervision in childcare and school environments, neurological vulnerability to hypoglycemia and hyperglycemia in young children, and potential adverse neurocognitive effects of Diabetic Ketoacidosis (DKA) (Barnea-Goraly et al., 2014; Cameron et al., 2014).

DKA is a serious complication of relative insulin deficiency, primarily affecting individuals with type 1 DM. However, it can also occur among individuals with type 2 DM when insulin levels fall significantly short of the body's needs. DKA is characterized by high levels of water-soluble ketone bodies, leading to an acidotic physiological state (Agarwal, 2019; Kamal et al., 2015). In children with an established diagnosis of type 1 DM, DKA occurs at an annual rate of 6–8 % (Cengiz., 2014; Rewers et al., 2002).

Based on the International Society for Pediatric and Adolescent Diabetes (ISPAD) guidelines, DKA is characterized by the biochemical triad of hyperglycemia (serum glucose >11 mmol/L or > 200 mg/dL),

* Corresponding author at: Hamad Medical Corporation (HMC), Doha, Qatar.
E-mail addresses: ahmad.juma@aaup.edu (A. Ayed), a.batran@paluniv.edu.ps (A. Batran), mohammadbash@aabu.edu.jo (M.A.L. Bashtawy), yahya84@bau.edu.jo (Y. Najjar), o.alkouri@yu.edu.jo (O. Alkouri), a_momani@asu.edu.jo (A. Momani), anashwan@hamad.qa (A.J. Nashwan), Anas.ababneh@yu.edu.jo (A. Ababneh).

https://doi.org/10.1016/j.pedn.2025.01.015

ketonemia (β-hydroxybutyrate concentrations >3.0 mmol/L) and/or moderate or large ketonuria, and a high anion-gap metabolic acidemia (venous pH < 7.3 and/or bicarbonate <18 mmol/L) (N. Glaser et al., 2022; Mayer-davis et al., 2018). Clinically, DKA is characterized by dehydration, tachypnea, Kussmaul breathing, the smell of ketones in the breath, nausea, vomiting, abdominal pain, drowsiness, confusion, reduced level of consciousness, and coma, which are precipitated by a variably long period of polyuria, polydipsia, and weight loss. Most children presenting with DKA are in a volume-depleted state, which, in its most severe form, results in acute tubular necrosis and potentially acute kidney injury (N. Glaser et al., 2022). Cerebral edema is a serious complication of DKA, with a mortality rate between 21 and 24 % (Edge et al., 2001). Cerebral edema results in chronic central nervous system morbidity in 10–25 % of children (Marcin et al., 2002). Furthermore, mild cerebral edema may cause minor mental status changes or, in some cases, may be asymptomatic (Ghetti et al., 2010; Glaser et al., 2006; Lawrence et al., 2005; Marcin et al., 2002; Watts & Edge, 2014).

Several risk factors for cerebral edema have been identified, including younger age, new onset DKA, administration of large volumes of fluid, insulin administration within the first hour of fluid treatment, administration of sodium bicarbonate, and insulin bolus administration (Watts & Edge, 2014). In response to these risk factors, the American Diabetes Association (ADA) established guidelines in 2006 for the care of pediatric patients with DKA. These guidelines recommend initiating fluid therapy immediately after recognizing DKA, limiting fluid administration to no more than 40 mL/kg over 2–4 h, using only isotonic fluids (such as 0.9 % saline or Lactated Ringer's) for the first 4–6 h, administering insulin at least 1 h after fluid resuscitation has begun (not concurrently), and using an insulin infusion rather than a bolus (Wolfsdorf et al., 2006).

This study aims to provide further evidence about the effectiveness of implementing the ADA American Association guidelines to manage DKA among children. This will guide clinicians, researchers, and stakeholders in implementing the guidelines above to achieve optimal outcomes when managing emergent DKA cases among children. In this study, we aimed to test the outcomes of implementing these recommended guidelines by the American Diabetes Association (ADA) (e.g., fluids and insulin administration guidelines) on vital signs, pH, HCO3-, and random blood glucose (RBG) taken by skin puncture (capillary sample) in the emergency department of Rafedia hospital in Palestine, which, to the best of our knowledge, was not tested before.

Methods

Study design and setting

A prospective cohort study was conducted among children with DKA admitted to Rafedia Hospital in Nablus City from February to May 2021. Rafedia is a government referral hospital that provides emergency and medical care to patients from the entire North West Bank area. The hospital's pediatric ward contains 35 beds and includes a three-bed Pediatric Intensive Care Unit. This study was reported using the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist, and additional details are provided in Supplementary File 1.

Participants

A convenience sampling technique was used to recruit children under 12 who attended the emergency department at Rafedia Hospital. Inclusion criteria were children under 12, patients with newly or previously diagnosed type 1 DM who met the criteria for DKA upon arrival at the emergency department, and those developing DKA. This criteria included: hyperglycemia (serum glucose >11 mmol/L or > 200 mg/dL), ketonemia (β-hydroxybutyrate concentrations >3.0 mmol/L), and a high anion-gap metabolic acidemia (venous pH < 7.3 and/or bicarbonate <18 mmol/L) (N. Glaser et al., 2022; Mayer-davis et al., 2018). Participants' legal guardians, such as parents, signed a consent form to demonstrate voluntary participation.

The minimum sample size required at $\alpha = 0.05$ level of significance, with a power of 0.8 and a medium effect size of 0.3, will be 58 participants (Erdfelder et al., 2009).

Study instrument

The study instrument included descriptive variables for patients with newly or previously diagnosed type 1 DM who met the criteria for DKA upon arrival at the emergency department such as age (years), gender (male, female), newly diagnosed type 1 DM (yes, no), duration of type 1 DM, family history of type 1 DM (yes, no), glycated hemoglobin (HbA1c) (%), and body mass index (BMI) (kg\m^2).

The study instrument also included the outcome of interest, mainly the impact of implementing guidelines such as fluids resuscitation and insulin therapy on i) vital signs, including blood pressure, heart rate, respiratory rate, O_2 saturation, and body temperature. Qualified nurses measured all vital signs according to routine practice in the hospital; ii) pH and bicarbonate (HCO_3^-) levels, which were measured using arterial blood gases (ABGs) samples; and iii) RBG levels, which were measured using regular glucose checks.

Ethical considerations

Ethical approval for the study was obtained from the Arab American University and the Palestinian Ministry of Health (Approval No.2021/309/162). Healthcare providers, including nurses and doctors, were fully informed about the study's objectives and procedures. Parents of children in the study provided formal written consent after being informed about the study's objectives. To ensure anonymity and confidentiality, all study participants were assigned codes. Data will be kept for five years in a locked cabinet at the Arab American University.

Data collection and procedures

After gaining relevant ethical approvals, the study was advertised to facilitate data collection. Each child underwent a comprehensive physical assessment and pertinent laboratory tests upon admission. After confirming that all inclusion criteria were met for each participant, the researchers gathered the necessary data. This process involved filling out a structured data sheet by the primary investigator that encompassed several key aspects: socio-demographic characteristics and assessment of each vital sign, pH and bicarbonate (HCO_3^-), and RBG upon arrival and post-fluid resuscitation (1–4 h later). All measurements of the study variables were conducted by professional nurses working in the research setting. To diagnose children with DKA, a child should have hyperglycemia (i.e., blood glucose > 200 mg/dL), venous pH < 7.3, and/or HCO_3^- < 18 mmol/L (Dunger et al., 2004; N. Glaser et al., 2022) in addition to ketonemia or moderate or high ketonuria (N. Glaser et al., 2022). The implemented clinical guidelines (i.e., fluid resuscitation and insulin therapy) by clinicians to manage the DKA of the study participants were reported based on the documentation in medical records.

Data analysis

The data were analyzed using the Statistical Package for the Social Sciences (Statistics, 2015). Descriptive statistics such as frequency distributions, means, standard deviations, and percentages were employed to summarize the data. In addition, inferential statistics, including repeated measures ANOVA, were utilized to examine relationships and differences within the data. Statistical significance was set at $p < 0.05$, indicating statistically significant results.

Results

Participants characteristics

Sixty children with DKA participated in this study, with an average age of 9.38 ± 3.13 years. The sample included 29 (48.3 %) males and 31 (51.7 %) females. The average body mass index was 17.84 ± 2.79. Most children were not newly diagnosed with type 1 DM (46,76.7 %). Among those previously diagnosed with type 1 DM, the average duration since diagnosis was 2.26 ± 1.886 years.

Furthermore, 68.3 % of the children had no family history of type 1 DM in a first-degree relative. Upon arrival, the average glycated hemoglobin (HbA1c) level was 11.74 ± 2.042. Table 1 presents the detailed descriptive data of the study participants.

Repeated-measures ANOVA also revealed significant differences in mean pH ($F = 20.4$, $p < 0.001$) and bicarbonate (HCO_3^-) ($F = 136.74$, $p < 0.001$) scores across the five different time points after administering the recommended fluids and insulin (Table 3).

Discussion

This study tested the outcomes of the recommended guidelines for DKA management among children, which included fluid and insulin administration. The results showed significant improvement in vital signs, pH levels, $HCO3^-$ and RBG outcomes over six hours after the initial emergency visit and DKA diagnosis. This study provided evidence that these recommended guidelines effectively manage children with DKA.

Our study showed significant improvement in vital signs readings such as BP, HR, O2 Sat, and body temperature. The results mirror a previous study that found that initial fluid therapy in pediatric DKA significantly changed vital sign parameters (Shafi & Kumar, 2018). The current study also demonstrated a significant improvement in mean pH and HCO3 scores over the follow-up period of 6 h. These results align with the results of Ugale et al. (2012), who measured the severity of DKA among children by comparing admission and follow-up values (Ugale et al., 2012). They assessed DKA severity based on physical examinations and blood gas values, categorizing patients into mild (14 %), moderate (27 %), and severe (59 %) DKA, which correlated with abnormal ABG's values. Ugale et al. (2012) found significant differences in DKA severity at various time points between arrival and 4–6 h after initiating fluid and insulin therapy (Ugale et al., 2012). In contrast, Balmier et al. (2019) found that median recovery times did not differ significantly among 120 children with type 1 DM despite receiving lower insulin doses, and hypoglycemia was more frequent in these patients (76.9 %), indicating a higher rate of metabolic complications and similar recovery times (Balmier et al., 2019). The differences in outcomes between these studies could be related to differences in patients' characteristics (i.e., age), treatment protocols, or the high rate of hypoglycemia.

The current study demonstrated a significant improvement in mean RBG scores over the follow-up period of 4 h. This finding highlights the effectiveness of timely intervention in managing DKA in pediatric patients. The observed decrease in RBG levels indicates a rapid response to treatment protocols, typically fluid resuscitation and insulin therapy. The effect of insulin on the reduction of glucose levels was shown in a previous study in which the administration of insulin resulted in a decline in plasma glucose levels, and this was explained as insulin can also decrease the hepatic glucose output (Luzi et al., 1988). Similarly, another study found that fast-acting insulin significantly reduces capillary blood glucose levels (Della Manna et al., 2005). The improvement in RBG scores is crucial as it reflects the stabilization of blood glucose levels, reducing the risk of further metabolic complications. This outcome underscores the importance of continuous monitoring and prompt treatment adjustments in the acute management of DKA, ensuring better patient outcomes within a short timeframe.

Strengths and limitations

The major strengths of this study are its novelty in the Palestinian context and the prospective nature of the study. This study is not exempt from some limitations. First, the design used is not optimal for assessing effectiveness, and we recommend clinical trials to assess the effectiveness of insulin and fluids management on DKA outcomes. Second, the observation period of the study outcome was only six hours, and we recommend longer observation in future investigations. Third, the sample size was small. Last, the outcomes measured are limited, and we suggest testing further outcomes in future research.

Implications

We believe that the results of this study have some valuable implications. As this study showed that implementing the recommended guidelines to manage DKA among children resulted in a significant improvement in different clinical outcomes, there is a need to consider these findings by clinicians and stakeholders. Clinicians need to adhere to the recommended guidelines when managing DKA among children to achieve the best clinical results. On the other hand, stakeholders need to support continuous professional development for clinicians, and this includes education and training about the importance of adherence to and being up to date with evidence-based guidelines in routine clinical practice when managing DKA among children. Furthermore, improving the outcomes while managing DKA in children will help in promoting the health of children with type 1 DM and without more severe complications such as cerebral edema. It is necessary to educate both children with type 1 DM and their caregivers for better control of DM and preventing its complications since DKA reflects reduced awareness about DM symptoms and its complications (Burcul et al., 2019).

The study results demonstrate the importance of the implementation of the recommended guidelines to manage DKA among children, which has the potential promise to influence pediatric nursing theory and practice. Future research in pediatric nursing should focus on assessing adherence to these guidelines by pediatric nurses and its associated factors. Pediatric nurses need to know the significance of implementing the recommended DKA guidelines to achieve the best clinical outcomes. Policies related to pediatric nursing practice should be rigorous in applying the recommended guidelines of managing pediatric DKA and updates frequently. Moreover, nursing

Table 1
Demographic characteristics of participants (number (%) or mean ± SD (Standard Deviation).

Characteristics	Total
Numbers	60
Age	9.38 (3.13)
Gender	
(Male)	29 (48.3)
(Female)	31 (51.7)
Newly diagnosed with type 1 diabetes	
Yes	14 (23.3)
No	46 (76.7)
Duration of type 1 diabetes	2.26 (1.9)
Family history of type 1 diabetes	
Yes	19 (31.7)
No	41 (68.3)
HbA1C (baseline)	11.74 (2)
BMI	17.8 (2.8)

Repeated-measures ANOVA revealed significant differences in mean systolic ($F = 89.8$, $p < 0.001$), diastolic ($F = 51.8$, $p < 0.001$) blood pressure, heart rate ($F = 134.0$, $p < 0.001$), respiratory rate ($F = 168.2$, $p < 0.001$), oxygen saturation ($F = 0.557$, $p < 0.013$), and temperature ($F = 4.435$, $p < 0.020$) scores across six different time points after administering the recommended fluids and insulin according to the guidelines (Table 2).

Table 2
Repeated measure ANOVA of vital signs (mean (SD)) ($N = 60$).

Vital signs	Baseline	After fluid resuscitation	After starting fluid and insulin therapy (1 h)	After starting fluid and insulin therapy (2 h)	After starting fluid and insulin therapy (3 h)	After starting fluid and insulin therapy (4 h)	*F*	*p*. value
Systolic BP	102.3(10.9)	107.8(9.2)	110.7(7.5)	113.4(6.5)	116.0(4.9)	116.3(4.7)	89.8	0.001
Diastolic BP	57.3(7.3)	62.2(6.5)	63.9 (6.5)	66.3(5.4)	67.1(6.4)	67.3(5.9)	51.8	0.001
HR	134.8(16.5)	129.2(16.1)	122.4(16.8)	118.7(15.5)	113.3(15.4)	110.5(14.3	134.0	0.001
RR	39.9(8.7)	36.9(7.7)	34.2(7.3)	31.3(7.1)	30.7(6.7)	29.4(6.8)	168.2	0.001
O_2 Sat.	97.1(1.6)	97.2(1.2)	97.1(1.3)	97.4(1.3)	97.2(1.1)	97.3(1.3)	0.557	0.013
Temp.	37.1(0.4)	37.0(0.3)	36.9(0.1)	36.9(0.1)	36.9(0.1)	36.9(0.1)	4.435	0.02

Note: p. values are significant at the 0.05 level.
Abbreviations: BP: blood pressure; HR: heart rate; RR: respiratory rate; O_2 sat: O_2 saturation; Temp.: temperature.

Table 3
Comparison between PH and HCO3^{-} (mean (SD)) across five different time points ($N = 60$).

Analysis	Baseline	After fluid resuscitation	After starting fluid and insulin therapy (2 h)	After starting fluid and insulin therapy (4 h)	After starting fluid and insulin therapy (6 h)	*F*	*p*. value
PH	7.07(0.15)	7.17(0.27)	7.19(0.10)	7.23(0.09)	7.26(0.09)	20.4	0.001
HCO_3^-	8.31(3.49)	9.05(3.08)	10.23(3.17)	11.49(3.26)	13.00(3.29)	136.74	0.001

Repeated-measures ANOVA also determined that mean RBG ($F = 160.58$, $p < 0.001$) scores differed significantly across six-time points (Table 4).

Table 4
Repeated measure ANOVA of RBG (mean (SD)) ($N = 60$).

Variable	Baseline	After fluid resuscitation	Random blood glucose After starting fluid and insulin therapy (1 h)	After starting fluid and insulin therapy (2 h)	After starting fluid and insulin therapy (3 h)	After starting fluid and insulin therapy (4 h)	*F*	*p*. value
RBG	497.80 (142.57)	395.52 (119.87)	299.20 (96.59)	246.13 (80.06)	198.98 (66.73)	210.08 (62.78)	160.581.	0.001

interventions focused on family education—such as teaching insulin administration, monitoring glucose levels, and recognizing warning signs—are integral to long-term management. This approach aligns with the findings that most patients in this study were not newly diagnosed but had experienced challenges in disease control, highlighting the importance of targeted education to prevent recurrent DKA episodes. Ensuring that families receive this education during and after hospitalization bridges the gap between acute care and long-term disease management, ultimately improving outcomes and reducing hospital readmissions.

Conclusion

The study confirmed improvement in the outcomes of DKA children with type 1 DM when implementing evidence-based guidelines. Significant improvements were observed in vital signs, pH and bicarbonate levels, and RBG. Overall, this study proved that interventions, including insulin administration and fluid resuscitation, are associated with positive outcomes during the initial follow-up of emergent DKA cases among children.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical considerations

Ethical approvals for conducting the study were obtained from both the Arab American University and the Palestinian Ministry of Health. Healthcare providers, including nurses and doctors, were fully informed about the study's objectives and procedures. Parents of children included in the study provided formal written consent after being informed about the study's objectives and their right to refuse participation or withdraw at any time. To ensure anonymity and confidentiality, all study participants were assigned codes.

CRediT authorship contribution statement

Majdi Younis: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Ahmad Ayed:** Writing – review & editing, Writing – original draft, Methodology. **Ahmad Batran:** Writing – review & editing, Writing – original draft, Methodology. **Mohammed A.L. Bashtawy:** Writing – review & editing, Writing – original draft, Methodology. **Yahya Najjar:** Writing – review & editing, Writing – original draft, Methodology. **Osama Alkouri:** Writing – review & editing, Writing – original draft, Methodology. **Aaliyah Momani:** Writing – review & editing, Writing – original draft, Methodology. **Abdulqadir J. Nashwan:** Writing – review & editing, Writing – original draft, Methodology. **Anas Ababneh:** Writing – review & editing, Writing – original draft, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thank the patients who participated in the study. The publication of this article was funded by the Qatar National Library.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pedn.2025.01.015.

References

Agarwal, H. S. (2019). Subclinical cerebral edema in diabetic ketoacidosis in children. *Clinical Case Reports*, *7*(2), 264–267. https://doi.org/10.1002/ccr3.1960.

Balmier, A., Dib, F., Serret-Larmande, A., De Montmollin, E., Pouyet, V., Sztrymf, B., ... Roux, D. (2019). Initial management of diabetic ketoacidosis and prognosis according to diabetes type: A French multicentre observational retrospective study. *Annals of Intensive Care*, *9*(1). https://doi.org/10.1186/s13613-019-0567-y.

Barnea-Goraly, N., Raman, M., Mazaika, P., Marzelli, M., Hershey, T., Weinzimer, S. A., ... Reiss, A. L. (2014). Alterations in white matter structure in young children with type 1 diabetes. *Diabetes Care*, *37*(2), 332–340. https://doi.org/10.2337/dc13-1388.

Burcul, I., Arambasic, N., Polic, B., Kovacevic, T., Bartulovic, I., Ardalic, T. C., & Markic, J. (2019). Characteristics of children with diabetic ketoacidosis treated in pediatric intensive care unit: Two-center cross-sectional study in Croatia. *Medicina (Lithuania)*, *55*(7), 1–8. https://doi.org/10.3390/medicina55070362.

Cameron, F. J., Scratch, S. E., Nadebaum, C., Northam, E. A., Koves, I., Jennings, J., ... Inder, T. E. (2014). Neurological consequences of diabetic ketoacidosis at initial presentation of type 1 diabetes in a prospective cohort study of children. *Diabetes Care*, *37*(6), 1554–1562. https://doi.org/10.2337/dc13-1904.

Cengiz. (2014). T1DM exchange clinic registry: Hypglycemia and DKA. *Pediatric Diabetes*, *14*(6), 447–454. https://doi.org/10.1111/pedi.12030.Severe.

Della Manna, T., Steinmetz, L., Campos, P. R., Farhat, S. C. L., Schvartsman, C., Kuperman, H., ... Damiani, D. (2005). Subcutaneous use of a fast-acting insulin analog. *Diabetes Care*, *28*(8), 1856–1861. https://doi.org/10.2337/diacare.28.8.1856.

Dunger, D. B., Sperling, M. A., Acerini, C. L., Bohn, D. J., Daneman, D., Danne, T. P. A., ... Wolfsdorf, J. I. (2004). ESPE/LWPES consensus statement on diabetic ketoacidosis in children and adolescents. *Archives of Disease in Childhood*, *89*(2), 188–194. https://doi.org/10.1136/adc.2003.044875.

Edge, J. A., Hawkins, M. M., Winter, D. L., & Dunger, D. B. (2001). The risk and outcome of cerebral oedema developing during diabetic ketoacidosis. *Archives of Disease in Childhood*, *85*(1), 16–22. https://doi.org/10.1136/adc.85.1.16.

Erdfelder, E., Faul, F., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149.

Ghetti, S., Lee, J. K., Sims, C. E., DeMaster, D. M., & Glaser, N. S. (2010). Diabetic ketoacidosis and memory dysfunction in children with type 1 diabetes. *Journal of Pediatrics*, *156*(1), 109–114. https://doi.org/10.1016/j.jpeds.2009.07.054.

Glaser, N., Fritsch, M., Priyambada, L., Rewers, A., Cherubini, V., Estrada, S., ... Codner, E. (2022). ISPAD clinical practice consensus guidelines 2022: Diabetic ketoacidosis and hyperglycemic hyperosmolar state. *Pediatric Diabetes*, *23*(7), 835–856. https://doi.org/10.1111/pedi.13406.

Glaser, N. S., Wootton-Gorges, S. L., Buonocore, M. H., Marcin, J. P., Rewers, A., Strain, J., ... Kuppermann, N. (2006). Frequency of sub-clinical cerebral edema in children with diabetic ketoacidosis. *Pediatric Diabetes*, *7*(2), 75–80. https://doi.org/10.1111/j.1399-543X.2006.00156.x.

Kamal, A., Travis, W., Montgomery, E. E., Kirby Michele, L., Ahmed Rami, A., Cooper Dylan, D., ... Abu-Sultaneh, S. M. (2015). Improving pediatric diabetic ketoacidosis management in community emergency departments using a simulation-based collaborative improvement program. *Pediatric Emergency Care*, *37*(11), 543–549.

Lawrence, J. M., Divers, J., Isom, S., Saydah, S., Imperatore, G., Pihoker, C., ... D. D. (2021). Trends in prevalence of type 1 and type 2 diabetes in children and adolescents in the US, 2001-2017. *JAMA*, *326*(8), 717–727.

Lawrence, S. E., Cummings, E. A., & Gaboury, I. (2005). Population-based study of incidence and risk factors for cerebral edema in pediatric diabetic ketoacidosis. *The Journal of Pediatrics*, *146*(5), 688–692.

Luzi, L., Barrett, E. J., Groop, L. C., Ferrannini, E., & DeFronzo, R. A. (1988). Metabolic effects of low-dose insulin therapy on glucose metabolism in diabetic ketoacidosis. *Diabetes*, *37*(11), 1470–1477. https://doi.org/10.2337/diab.37.11.1470.

Marcin, J. P., Glaser, N., Barnett, P., McCaslin, I., Nelson, D., Trainor, J., ... Kuppermann, N. (2002). Factors associated with adverse outcomes in children with diabetic ketoacidosis-related cerebral edema. *Journal of Pediatrics*, *141*(6), 793–797. https://doi.org/10.1067/mpd.2002.128888.

Mayer-davis, E. J., Kahkoska, A. R., Jefferies, C., Dabelea, D., Gong, C. X., Aschner, P., & Craig, M. E. (2018). ISPAD Clinical Practice Consensus Guidelines 2018: Definition, epidemiology, and classification of diabetes in children and adolescents. *Pediatric Diabetes*, *19*(Suppl. 27), 7–19. https://doi.org/10.1111/pedi.12773.ISPAD.

Rewers, A., Chase, H. P., Mackenzie, T., Walravens, P., Roback, M., Rewers, M., Hamman, R. F., & Klingensmith, G. (2002). Predictors of acute complications in children with type 1 diabetes. *JAMA*, *287*(19), 2511–2518.

Shafi, O., & Kumar, V. (2018). Initial fluid therapy in pediatric diabetic ketoacidosis: A comparison of hypertonic saline solution and normal saline solution. *Pediatric Endocrinology, Diabetes and Metabolism*, *24*(2), 56–64. https://doi.org/10.18544/PEDM-24.02.0103.

Statistics, I. B. M. S (2015). *IBM SPSS statistics for windows (No. 23)*. Armonk: IBM Corp.

Ugale, J., Mata, A., Meert, K. L., & S. A. (2012). Measured degree of dehydration in children and adolescents with type 1 diabetic ketoacidosis. *Pediatric Critical Care Medicine*, *13*, e103–e107.

Watts, W., & Edge, J. A. (2014). How can cerebral edema during treatment of diabetic ketoacidosis be avoided? *Pediatric Diabetes*, *15*(4), 271–276.

Wolfsdorf, J., Glaser, N., & Sperling, M. A. (2006). Diabetic ketoacidosis in infants, children, and adolescents: A consensus statement from the American Diabetes Association. *Diabetes Care*, *29*(5), 1150–1159. https://doi.org/10.2337/dc06-9909.