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Review Article

Glycemic Control of Children and Adolescents with Type 1 Diabetes in the United Arab Emirates: A Narrative Review.

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Abstract

Background Diabetes is the fastest-growing chronic disease in the world with increased morbidity and mortality associated with a diagnosis at a young age. The landscape of glycemic control of children and adolescents in the United Arab Emirates, a dynamic and fast evolving country in the Middle East, is unknown, potentially limiting decisions around patient care, health system planning, and efforts around advocacy.
Aim This article determines the reported glycemic control of this vulnerable population, and factors influencing blood glucose management.
Methods A quantitative epidemiological narrative review was conducted using PubMed, CINAHL, and Cochrane databases, searched from 2012 to 2023. English studies involving the study population were reviewed and appraised.
Results Overall, 16 studies were included, mainly heralding from Abu Dhabi and involving Emirati nationals. Reported mean hemoglobin A1c (HbA1c) ranged from 7.9 to 9.6% (63–81 mmol/mol) and diabetes-related technology use was high. Themes identified were diabetes and technology, education, psychology, and Ramadan.
Conclusion Glycemic control was suboptimal, with mean HbA1c being hyperglycemic across included studies, despite a high use of diabetes-related technology. Unless change is made, children and adolescents and young adults with type 1 diabetes will likely experience unnecessary morbidity and mortality.

Keywords
- education
- pediatrics
- psychology
- technology
- type 1 diabetes
- United Arab Emirates

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Introduction

Diabetes is the fastest growing chronic disease in the world.[1] An estimated 537 million adults aged 20 to 79 years are thought to be living with the disease worldwide, and based on current trajectories, it is estimated that 630 million adults will be living with diabetes by 2030, and around 783 million by 2045.[1] In children and adolescents, the most prevalent kind of diabetes is type 1, while type 2 diabetes, monogenic diabetes, and other types also exist.[1] This is particularly problematic considering increased morbidity and mortality associated with having the disease at such a young age.[2] Being diagnosed with type 1 diabetes at 10 years of age results in the loss of an estimated 20 life-years.[3]

The United Arab Emirates, a high-income country in the Middle East, is located at the eastern end of the Arabian Peninsula.[1] It shares borders with Oman and Saudi Arabia, while having maritime borders in the Persian Gulf with Qatar and Iran. As with many other countries, the United Arab Emirates does not have a national registry to accurately assess the type 1 diabetes incidence and prevalence. Extrapolating data from nearby Oman, the International Diabetes Federation's 2021 Atlas[1] estimates that the United Arab Emirates had an estimated 503 incidence and 4,000 prevalence of type 1 diabetes in children and adolescents aged < 20 years, an 8% increase over the previous 2 years. However, the evolving Type 1 Diabetes Index estimates that a total of 14,129 people live with type 1 diabetes in the United Arab Emirates, of which 1,694 are aged < 20 years.[3] Therefore, there is a pressing need for comprehensive health care service provision to promote positive health-related outcomes for those with type 1 diabetes.

Access to health care in the United Arab Emirates is, however, fragmented. While free medical care is provided to United Arab Emirates nationals, mainly in government facilities, much of the population consists of expatriates who mainly access private health care through using employer-provided private health insurance.[4] While private health insurance is mandatory to be provided by employers for all their employees, this insurance can have limitations based on the category of cover, which is chosen at the discretion of the employer.[5] Coverage usually includes access to physician consultations and investigatory procedures, with coverage for other health care professionals only being available for nationals, who are seen in a government facility that has all relevant diabetes services.[6] Further, coverage also requires preapproval, which affects patient flow and pathways within a diabetes service, especially for the expatriate community. Another challenge in the United Arab Emirates is workforce—with a reliance upon expatriate workers—there is often a high staff turnover and a subsequent delay of replacing staff, including health due to stringent licensing regulations required by different Emirates and entities.[7]

International consensus clinical guidelines indicate that the target hemoglobin A1c (HbA1c) of young people with diabetes should be at least < 7.0% (< 53 mmol/mol)[2]; a with a lower target of 6.5% (< 48 mmol/mol) being recommended for the remission phase or early stage 3 phase "honeymoon" period in populations with access to advanced technology, combined with a highly skilled specialized health care professional service adept in diabetes education.[2] The landscape of glycemic control of children and adolescents with type 1 diabetes aged ≤ 18 years in the United Arab Emirates is unknown, potentially limiting decisions around patient care, health system planning, and efforts around advocacy. We undertook a literature review with the aim of determining the reported glycemic control of this vulnerable population.

Methods

A narrative review was conducted using processes adapted from established review methods set out by the Centre for Reviews and Dissemination.[8] Standards derived from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were applied.[9]

Literature Search Methods

PubMed, CINAHL, and Cochrane databases were searched by the first author from January 2012 to November 2023. A comprehensive set of Medical Subject Headings, keywords, and Boolean operators were used to retrieve literature (►**Supplementary Material S1**, available in online version). In addition, the reference lists of all included records were hand searched.

Inclusion criteria were:

- Individuals with type 1 diabetes aged ≤ 18 years (including where related data were provided as part of a wider age group).
- Data collected from United Arab Emirates populations.
- Studies published in English language only due to lack of resources for translation.

Exclusion criteria were:

- Studies reporting data collected prior to 2012. From 2012, type 1 diabetes management in the United Arab Emirates has changed; in part due to the introduction and increased use of diabetes-related technology, local diabetes guidelines having been published,[10] and a rise in diabetes research.[11]
- Nonprimary studies.

Search Outcome

A total of 454 articles were identified, downloaded to Covidence, and screened by reading titles and abstracts (►**Fig. 1**). Of these, 385 articles were excluded as duplicates or not meeting review inclusion criteria. The remaining 69 full-text articles were assessed for eligibility. Of these, 53 did not meet review inclusion criteria, leaving 16 relevant articles.[12–27]

Quality Appraisal

To determine the strength of evidence, quality appraisal was undertaken using the Joanna Briggs checklists for Systematic Reviews and Research Synthesis (►**Supplementary Material S2**, available in online version). To ensure reliability in data extraction and quality appraisal, a sample of articles included in the review were independently appraised and data

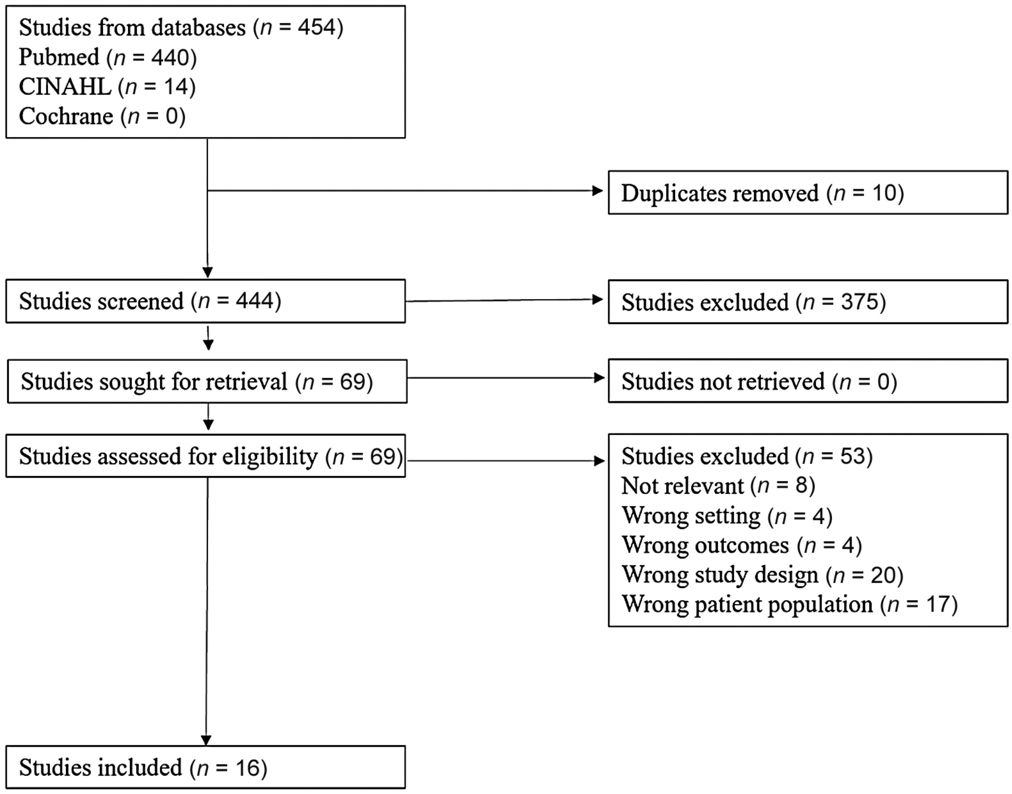

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart.[9]

extraction compared by the second author (seven papers). Agreement was reached for all included articles.

Data Extraction and Synthesis

Data were extracted to a purpose-designed spreadsheet in Microsoft Office Excel based on relevant elements of the Consolidated Standards of Reporting Trials (CONSORT) checklist[28] (►**Table 1**).

Results

Of the 16 articles identified, 15 (94%) heralded from Abu Dhabi, of which 9 were undertaken by one research group. All articles were published between 2012 and 2023 and were conducted in government hospitals or health care facilities, with most of the studies involving Emirati nationals. No articles were retrieved that only explored glycemic control with HbA1c as their primary outcome. Therefore, the glycemic control of the target cohort was determined by examining the baseline or preintervention data from included articles, as appropriate. Of the included articles, 14 provided data solely relating to the children and adolescents with type 1 diabetes. After examining the baseline or preintervention data from all included studies, overall mean baseline HbA1c levels across these studies ranged from 7.9% (63 mmol/mol) to 9.6% (81 mmol/mol).

All included articles provided additional insight into factors influencing this glycemic control. Accordingly, the four main themes that emerged from the included articles were: diabetes-related technology, diabetes education, diabetes and psychology, and diabetes and Ramadan—the ninth month of the Islamic calendar, observed by Muslims as a month of fasting, prayer, reflection, and community.[29] This form of fasting involves the abstinence of food and water from sunrise to sunset, daily. The primary outcomes for these studies, while not HbA1c change, included outcomes such as frequency of glucose monitoring, frequency and duration in hypoglycemia, postprandial hyperglycemia, rates of diabetic ketoacidosis, change in HbA1c for those transitioning from multiple daily injections (MDIs) of insulin, to continuous subcutaneous insulin infusion (CSII), diabetes distress, and ability to safely fast during Ramadan.

Diabetes-Related Technology

Diabetes-related technology use was considered in most (n = 10, 63%) included articles. Glycemic control was mainly characterized by measuring HbA1c at baseline and when applicable, postintervention. Median HbA1c ranged from 8.1 to 9.7% (65–83 mmol/mol) and significantly depended on age group and insulin delivery method. When considering the importance of frequent glucose monitoring, one study looked at the impact of flash glucose monitoring in detecting hypoglycemia and enhancing adherence to diabetes management in 72 children and adolescents (age range 2–19 years) with type 1 diabetes and reported a mean (range) HbA1c of 8.2% (5.9–10.2%), 66.1 mmol/mol (41.0–88.0 mmol/mol).[12] Data from flash glucose monitoring were collected over a 2- to 4-week period and demonstrated 68 (94%) and 65 (90%) people

Table 1 Extracted data summarizing key information from included articles

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
Afandi et al (2017). Correlation between pre-Ramadan glycemic control and subsequent glucose fluctuation during fasting in adolescents with type 1 diabetes.					
Observational cohort	$n = 21$ Female = 15 Mean age = 15 (4) Diabetes duration (3 y)	Abu Dhabi	3 days of CGM data captured during Ramadan to compare with those with optimal control (7 patients) < 8% HbA1c vs. those with suboptimal control (14 patients) > 8%	Mean BG was 174 (76) vs. 199 (98) in the well vs. poorly controlled group	Small study group, mostly CSII ($n = 18$)
Almazrouei et al (2022). Continuous subcutaneous insulin infusion is associated with a better glycemic control than multiple daily insulin injections without difference in diabetic ketoacidosis and hypoglycemia admissions among Emiratis with type 1 diabetes.					
Cross-sectional retrospective study	$n = 134$ Female = 76 Mean age 20.9 (7.5) Duration of diabetes, 50% > 10 years	Abu Dhabi	To compare clinical outcomes as well as socioeconomic characteristics between Emirati pediatric patients with type 1 diabetes on MDI vs. CSII	• 50/50 split between CSII and MDI • 85.7% of CSII users had higher level of education compared to only 68.7% in MDI users • DKA reported in 46.3% • Average glycemic control over preceding 12 months was satisfactory (HbA1c < 7.5%) 26.6%, suboptimal (HbA1c 7.5–9%) 42.7%, and poor (HbA1c > 9%) in 30.6% of the patients • Higher proportion of patients using CSII achieved satisfactory or suboptimal glycemic control ($p = 0.003$) • HbA1c significantly lower ($p = 0.041$) in patients using CSII (8.2/1.93%) compared to MDI (8.5/2.45%) • No significant difference in DKA, severe hypoglycemia, or total WHO-5 score • 91.8% saw the dietitian < 3 times per year and 29.9% saw the diabetes educator < 3 times per year	Small study group 2 centers but from same Emirate and same resources. Mainly Emirati patients who have access to free health care service
Beshyah and Beshyah **(2019).** The incidence of diabetic ketoacidosis during Ramadan fasting: A 10-year single-center retrospective study.					
Retrospective observational		Abu Dhabi	Review relationship between DKA admissions and Ramadan period over 10 years	• 432 episodes of DKA from 283 patients of which 85.6% were those with type 1 diabetes. • The number of admission episodes on average per month was not different to the average for the month of Ramadan (3.6 episodes per month in Ramadan vs. 3.3 other months) not significantly higher	Single center study.

Table 1 (*Continued*)

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
Deeb et al. (2019). Impact of insulin injection and infusion routines on lipohypertrophy and glycemic control in children and adults with diabetes.					
Observational, cohort	$n = 169$ (104 children) 119 MDI 50 CSII 54 children on MDI and 50 on CSII. Mean age (SD) 12.11 (± 4.1) years Diabetes duration 4.08 (± 3.58) years	Abu Dhabi	Questionnaire given to patients plus injection/infusion sites checked by diabetes educators for LH and HbA1c measures to see correlation	• 72 and 82% of children and adults, respectively, rotate site at every injection • 78% of pump users change infusion set and 74% rotate site at 2–3 days • Children without LH had a mean (SD) HbA1c of 7.9 (1.02) (63 mmol/mol), while HbA1c for those who had LH was 9.0 (1.31) (75 mmol/mol). This difference was statistically significant (p 0.001)	Subjective questionnaires. Small sample size and single-center study
Deeb et al (2015). Important determinants of diabetes control in insulin pump therapy in patients with type 1 diabetes mellitus.					
Prospective observational, cohort	$n = 72$ (50 children median age 12 years)	Abu Dhabi, 2 centers	Variables studied: sensor use, frequency of blood glucose monitoring, Bolus Wizard (Medtronic Minimed) use, frequency of correction boluses, and frequency of cannula changing	• 20 children (40%) had HbA1c < 8% (controlled group) and 30 (60%) had HbA1c > 8% (uncontrolled group) • Respective median numbers of blood glucose checks were 4.4 and 3.2 for controlled vs. uncontrolled children ($p < 0.021$) • Frequency of Bolus Wizard use per day showed a median of 6 and 4.15 for controlled vs. uncontrolled children, respectively ($p < 0.001$) • Controlled children wore sensors for longer (5 vs.. 2.9 days/week) and did more corrections (3.9 vs. 2.5) but not statistically significant	
Deeb et al (2019). Using insulin pump with a remote-control system in young patients with diabetes improves glycemic control and enhances patient satisfaction.					
Prospective, observational cohort	$n = 38$ primary $n = 24$ (mean age 16) and secondary $n = 14$ (mean age 9)	Abu Dhabi, 2 centers	Addressed patients on MDI switching to an integrated pump system (primary: adolescents and young adults, secondary: school children). Treatment and patient satisfaction parameters were recorded at baseline and at two visits at 12 and 24 weeks	From baseline HbA1c 0f 9.7 and 8.7% for teens and children, respectively, to visit 2, the mean decrease of HbA1c was 1.09% ($p = 0.00009$) and 0.79% ($p = 0.09$) for the teens and children's group, respectively. Patient satisfaction rate was favorable. Exploratory analysis revealed patients favoring the use of the remote control achieved best reductions in HbA1c ($p = 0.0174$)	Small sample size. Study lack of comparison between users of the pump with or without the remote function

(*Continued*)

Table 1 (*Continued*)

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
Deeb et al (2017). Accurate carbohydrate counting is an important determinant of postprandial glycemia in children and adolescents with type 1 diabetes on insulin pump therapy.					
Prospective observational cohort	$n = 30$ (21 females) median age 13 years	Abu Dhabi	Patients instructed to keep food diary, estimate carbohydrate (CHO) count/meal, and record 2-hour postprandial glucose readings for 3–5 days. Meals' CHO contents were recounted by an experienced clinical dietician. Those within 20% of the dietician's counting were considered accurate	Data of 247 meals were analyzed. A total of 165 (67%) meals' CHO contents were accurately counted. Of those, 90 meals (55%) had in-target postprandial glucose • There was an inverse relationship between inaccurate CHO estimates and postprandial glucose • Of the 63 underestimated meals, 55 had above-target glucose, while 12 of the 19 overestimated meals were followed by low glucose	Small sample size. IG, fat, and protein and timing of bolus were not considered
Deeb et al (2017). Attitude, complications, ability of fasting and glycemic control in fasting Ramadan by children and adolescents with type 1 diabetes mellitus.					
Prospective observational, quasi-experimental	$N = 65$ mean age $= 14.5$ years Diabetes duration 5.7 years (38 on CSII and 27 on MDI)	Abu Dhabi	Two hospital visits whereby questionnaires were filled in at each visit and HbA1c recorded. Logbooks recording symptomatic hypoglycemia and/or hyperglycemia leading to breaking of the fast were reviewed	• 57 and 26% fasted more than half and all through the month, respectively • 52% had at least one episode of hypoglycemia and 29% had hyperglycemia with one episode of ketoacidosis • All patients broke their fast in response to symptomatic hypoglycemia/hyperglycemia • There was no significant difference between the frequency of complications in the pump or the MDI groups • Mean HbA1c increased from 70 to 73 mmol/mol	Small sample size
Deeb et al (2016). Does reducing basal insulin during Ramadan fasting by children and adolescents with type 1 diabetes decrease the risk of symptomatic hypoglycemia?					
Cross-sectional	$N = 68$ Mean age 14.5 years 41 on CSII 27 on MDI	Abu Dhabi	- Measured the impact of reducing basal insulin during Ramadan fasting on reducing the risk of symptomatic hypoglycemia leading to breaking fast - Logbooks marked days fasted, symptomatic hypoglycemia, and dose of basal insulin on all days of Ramadan - Logbooks were examined	• Mean HbA1c was 7.9% (1.2) and 8.4% (1.3) for the pump and the MDI, respectively ($p = 0.007$) • Thirty-nine patients had hypoglycemia leading to breaking fast • The mean number of episodes of breaking fast was 3 (1–8) • Thirty-five of the 68 patients had reduced basal insulin. The difference in the frequency of hypoglycemia in those who reduced/did not reduce	The findings would be more strongly validated if the study was planned in a prospective design

Table 1 (*Continued*)

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
			- Glucometers and insulin pumps were downloaded	insulin was not statistically significant ($p > 0.10$) • Fifteen patients on MDI and 24 patients on pumps had at least one episode of breaking fast • Six and 18 of the patients on MDI and pumps, respectively, reduced basal insulin ($p > 0.10$)	
Deeb et al (2017). Impact of targeted education on managing warning and error signals by children and adolescents with type 1 diabetes using the Accu-Chek Combo Insulin Pump System.					
Observational, cross-sectional	$N = 21$ Mean age = 13 Diabetes duration = 5 years Duration on CSII 2.5 years	Abu Dhabi	Targeted education on troubleshooting alarms and warnings on insulin pumps	• Numbers of warning and error signals markedly decreased after targeted education ($p < 0.05$) • The ability in decrypting warning signals significantly improved ($p = 0.02$) and the frequency of response to pump alarms significantly increased ($p = 0.001$)	Small sample size, short duration of follow-up, and lack of an analysis of the effect on glycemic control
Deeb et al (2016). Implementation of a diabetes educator care model to reduce pediatric admission for diabetic ketoacidosis.					
Longitudinal observational cohort	4 nurses trained as diabetes educators	Abu Dhabi	• Proposed a model of care led by diabetes educators for children and adolescents with diabetes • Team consisted of highly trained nurses • Effectiveness was measured by comparing the rate of hospital admission for DKA over a 4-year period to the baseline year prior to implementing the model	• 158 admissions for DKA over a 5-year period • DKA admissions showed a downward trend with percentage of DKA admissions reduced from 210% (2009) to 1.8% (2013) (p 0.001) • Number of patients followed up in the outpatient diabetes clinics increased from 37 to 331 patients at the start and the end of the study years	No control group to confirm effectiveness of this model of care
Deeb et al (2019). Novel ambulatory glucose-sensing technology improves hypoglycemia detection and patient monitoring adherence in children and adolescents with type 1 diabetes.					
Prospective, observational quasi-experimental	$n = 72$ Mean age 11.9 years	Abu Dhabi	• Impact of the flash ambulatory glucose monitoring in detecting hypoglycemia and enhancing adherence in children and	• 68 (94%) and 65 (90%) patients detected nocturnal and diurnal hypoglycaemia, respectively, on flash monitoring compared to 12 (16.6%) and 30 (41%) on glucometer testing	Single center, short duration of FCGM

(*Continued*)

Table 1 (*Continued*)

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
			adolescents with type 1 diabetes • Frequency of glucose monitoring duration and frequency of hypoglycemia were compared on conventional and the flash monitoring	($p < 0.01$) • Mean (range) duration of hypoglycemia was 95 min (15–330) • Statistically significant difference was found between the frequency of glucose monitoring on glucometer testing compared with flash monitoring (2.87 and 11.6/day) ($p < 0.001$)	
Hussain et al (2017). Comparative study on treatment satisfaction and health perception in children and adolescents with type 1 diabetes mellitus on multiple daily injection of insulin, insulin pump, and sensor-augmented pump therapy.					
Cross-sectional, observational	$n = 72$ (36 males) Mean age 11.4 years Diabetes duration 4.9 years	Abu Dhabi	Questionnaires interviewing patients with type 1 diabetes on their treatment satisfaction and health perception based on the treatment they are on (MDI, insulin pump, and sensor-augmented pump)	• Mean HbA1c 8.1% • Duration of wear of CGM was 17.7 days/month—Significant difference in scores showing higher treatment satisfaction for the pump/sensor-augmented pump vs. MDI • No statistical difference between the two pump groups	Low number of participants using sensor (19)
Kaplan et al (2017). Comparison of continuous glucose monitoring in adolescents with type 1 diabetes: Ramadan versus non-Ramadan.					
Prospective cohort	$n = 14$ Mean age 15 (±4) Diabetes duration 6 years	Abu Dhabi	Comparison of CGM data from days during Ramadan fasting and either before or after Ramadan. Measured mean interstitial glucose, hypoglycemia duration, hyperglycemia, and severe hypoglycemia	Mean baseline of HbA1c 8.6% data showed no difference on mean interstitial glucose, hypoglycemia, hyperglycemia, and severe hypoglycemia during or outside of Ramadan	Small sample size, small duration of time periods compared
Muammar et al (2022). Ramadan fasting among older children and adolescents with type 1 diabetes mellitus: A real-world study from the United Arab Emirates.					
Retrospective cohort	$n = 42$ (27 male) Mean age 13.5 years Diabetes duration 4.9 years 23 MDI, 19 CSII	Abu Dhabi	Implementation of CHOICE education program for those older children who chose to fast and measured indicators of glycemic control (HbA1c, hypos, and DKA frequency) before, during, and after Ramadan	Data show no significant deterioration in indicators of overall glycemic control which remained inadequate with HbA1c after Ramadan at 8.9% for MDI users and 8.4% for CSII users	Single-center study Small sample size
Younes et al (2021). Prevalence of diabetes distress and depression and their association with glycemic control in adolescents with type 1 diabetes in Dubai, United Arab Emirates.					
Cross-sectional observational	$n = 72$ 39 males/33 females Mean age 15.14 years	Dubai	Adolescents were asked to fill a questionnaire to assess relationship between glycemic	The mean HbA1c was 9.61% [82 mmol/mol] with higher levels found in females compared to males ($p < 0.05$)	Small sample size may lead to bias

Table 1 (*Continued*)

Type of study	n = male/female Mean age Diabetes duration	Emirate	Intervention	Results	Limitations
			control and distress or depression	• Females showed significantly greater levels of distress as compared with males • Adolescents with HbA1c ≥ 7.5% scored higher for diabetes distress and depression; however, the difference was not statistically significant to those with an HbA1c of < 7.5% • Higher levels of diabetes distress was highly correlated with depressive symptoms, with distress and depression both being significant predictors of one another	

Abbreviations: BG, blood glucose; CGM, continuous glucose monitoring; CHO, carbohydrate; CSII, continuous subcutaneous insulin infusion; DKA, diabetic ketoacidosis; FCGM, flash continuous glucose monitoring; HbA1c, hemoglobin A1c; IG, interstitial glucose; LH, lipohypertrophy; MDI, multiple daily injections; SD, standard deviation; WHO, World Health Organization.

had developed nocturnal and diurnal hypoglycemia, respectively, compared to 12 (16.6%) and 30 (41%) utilizing glucometer testing ($p < 0.01$). Despite these improvements, those using flash glucose monitoring still experienced a mean (range) duration of 95 minutes (15–330 minutes) in hypoglycemia.[12] Another study investigated clinical outcomes and socioeconomic characteristics between 134 Emirati nationals for teens and young adults with type 1 diabetes using either MDI or CSII therapy[13]; unfortunately, some of these participants were older than the age group criteria for the current literature review. There was no difference in rates of diabetic ketoacidosis, severe hypoglycemia or the World Health Organization-5 (well-being) scores. The overall median (standard deviation) HbA1c was 8.3% (1.9%), 67 mmol/mol (21 mmol/mol). Those using CSII had significantly lower ($p = 0.04$) median HbA1c 8.2% (1.93%), 66 mmol/mol (23 mmol/mol) compared to MDI 8.5% (2.45%), 69 mmol/mol (27 mmol/mol) ($p = 0.04$).[13] Despite better glycemic outcomes for users of CSII technology, 73% of the cohort had suboptimal glycemic control, having HbA1c greater than 7.5% (58 mmol/mol), with 45.5% of the cohort reporting diabetic ketoacidosis in the preceding 12 months. In addition, the frequency of health care professional visits was counted, with less than three annual visits to general practitioner (doctor), dietitian, and diabetes educator for 45.5, 91.8, and 29.9% of the study population, respectively.[13] Improvements in glycemic control when transitioning from MDI to CSII were also seen in another study, which demonstrated a HbA1c reduction of 1.1% for adolescents and young adults, and 0.8% for younger children (aged 6–11 years) when followed up at 24 weeks post-CSII initiation. However, the baseline HbA1c was high, with a mean of 9.7%, 83 mmol/mol, for the adolescents and young adults, and 8.7%, 72 mmol/mol for the younger children group.[14]

Deeb et al examined behaviors of those on CSII. The mean HbA1c in this cohort of 50 pediatric participants (median age 12 years), was 8.5% (1.4%), 69 mmol/mol (16 mmol/mol). They found that there was better glycemic control (HbA1c < 8%, 64 mmol/mol), accounting for 40% of participants, in those who had bolus insulin and checked their blood glucose levels more frequently (median number of blood glucose checks per day was 4.4), compared to those with suboptimal glycemic control (HbA1c ≥ 8%, 64 mmol/mol) (median number of blood glucose checks per day was 3.2).[15] In 2017, Deeb et al, further demonstrated that success relating to CSII was dependent on targeted education, specifically looking at troubleshooting alarms and warnings on insulin pumps. In 21 pediatric participants (median age 13 years) using CSII with mean HbA1c 8.1%, 65 mmol/mol, they reported a decrease in the number of warning and error signals after targeted education ($p < 0.05$); the ability to decrypt warning signals significantly improved ($p = 0.02$), and the frequency of response to CSII alarms significantly increased ($p = 0.001$). There was, however, no follow-up to determine if this education impacted on glycemic control or lowering of HbA1c.[16]

Diabetes Education

Three studies by Deeb et al demonstrated the importance of diabetes-trained health care professionals in providing self-management education as a foundation for improving and maintaining glycemic control. In one study, a model of care led by trained diabetes educators whose role was to provide diabetes self-management education, was effective in reducing diabetic ketoacidosis rates by 210-fold over a 5-year period, when compared to before the care model was implemented. This coincided with the total number of people followed up as outpatients increasing from 37 to 331.[17] Furthermore, in 2019 the research team also demonstrated the importance of diabetes education when considering injection and cannula site rotation. The study, consisting of 169 children, found those without lipohypertrophy had a mean (standard deviation) HbA1c of 7.9% (1.02%), 63 (11) mmol/mol while the HbA1c for those who had lipohypertrophy was 9.0% (1.3%), 75 (14) mmol/mol ($p = 0.001$).[18] Likewise, emphasis on the positive impact of teaching carbohydrate counting as an essential skill was demonstrated when 2 to 3 days of data were collected on 247 meals from 30 children. Upon review, two-thirds of the meals were considered to have been accurately counted and there was an inverse relationship between inaccurate carbohydrate estimates and postprandial glucose; 77% of inaccurately counted meals involved underestimation of carbohydrate, resulting in 67% of the postprandial blood glucose readings above the postprandial target range.[19]

Diabetes and Psychology

Two articles considered diabetes and psychology. In a study looking at diabetes distress and depression in relation to glycemic control, 72 adolescents with mean HbA1c of 9.6% (2.14), 82 mmol/mol (23 mmol/mol), completed a questionnaire to determine the relationship between glycemic control and distress or depression. No statistically significant difference in diabetes distress or depression was found between those with a HbA1c $< 7.5\%$ (53 mmol/mol) versus those $\geq$ 7.5%; females showed significantly higher HbA1c levels and were found to score significantly higher on diabetes distress as compared with males with a mean score of 37.8 (22.5) and 25.3 (17.2) for females and males, respectively ($p = 0.009$), with a greater percentage of females falling under the category of severe diabetes distress (42.4% of females vs. 20.5% of males; $p = 0.018$).[20] Finally, Hussain et al demonstrated that despite suboptimal glycemic control, the therapy used for diabetes treatment has an impact on people's satisfaction and health perception. In 72 patients with a mean HbA1c of 8.1% (1.2%), or 65 mmol/mol (13 mmol/mol), that those utilizing CSII had higher treatment satisfaction scores when compared with those using MDI therapy. MDI users had a statistically significant higher mean HbA1c of 8.5% (1.3%), or 69 mmol/mol (15 mmol/mol) when compared to those using insulin pump and sensor-augmented pumps, showing mean HbA1c of 8.0% (1.2%), 63 mmol/mol (14 mmol/mol).[21]

Diabetes and Ramadan

Six studies reported how teenagers who chose to fast managed their glucose levels during this fasting period. Glycemic control during Ramadan was suboptimal with as many as 66% of teens, from the six studies reviewed, commencing Ramadan fasting with a HbA1c $> 8.0\%$ (64 mmol/mol). In a study reviewing the frequency of symptomatic hypoglycemia and/or hypoglycemia leading to breaking of the fast, 52% of participants, age ranging from 10.2 to 18.8 years (median age 14.5 years), had a mean HbA1c of 8.6% (70 mmol/mol) and at least one hypoglycemic episode, while 29% had hyperglycemia with one episode of diabetic ketoacidosis. When considering acute glycemic complications, 26% were able to fast every day in the month of Ramadan, while 57% were able to fast for only half of the total Ramadan days.[22] Another study looked at whether reducing basal insulin rates for teens during the fasting hours would lead to less hypoglycemia frequency and subsequent breaking of fast. In this, the frequency of hypoglycemia in those who reduced, versus did not reduce their insulin dosages, was not statistically significant.[23] Similarly, Beshyah and Beshyah, looked at the relationship between diabetic ketoacidosis admissions and Ramadan over a 10-year period. They found no statistical significance between the average number of admissions for diabetic ketoacidosis per month to be any different to the month of Ramadan.[24] Likewise, another study found no statistically significant difference of hypoglycemia frequency, severe hypoglycaemia, and hyperglycemia captured from continuous glucose monitoring data during 3 days of fasting when compared to 3 days of nonfasting.[25]

Glycemic control prior to Ramadan also appears to also be indicative of glycemic control during Ramadan, with a study using continuous glucose monitoring data to measure glycemic control and compare those with well-controlled diabetes. This study involved 21 adolescents (mean age 15 years) with 7 being well controlled (HbA1c $< 8\%$, 64 mmol/mol) and 14 poorly controlled (HbA1c $> 8\%$, 64 mmol/mol) having continuous glucose monitoring data reviewed. The study demonstrated that those with a high average blood glucose prior to Ramadan continued along the same trajectory during Ramadan, compared to the ones with better glucose control prior to Ramadan.[26] Similarly, implementation of the CHOICE (Carbohydrate, Insulin, Collaborative Education) program for 42 adolescents with age range of 9 to 18 (13.5 ± 2.4) years who chose to fast, measured indicators of glycemic control (HbA1c, hypoglycemic episodes, and diabetic ketoacidosis frequency). There was no significant deterioration in indicators of overall glycemic control, which remained inadequate. Although overall their results indicated that Ramadan fasting did not appear to lead to worsening of glycemic control, their results did demonstrate that this fasting is not advised for those children who have poorly controlled type 1 diabetes.[27]

Discussion

This narrative literature review sought to determine the glycemic control of children and adolescents with type 1 diabetes aged $\leq$ 18 years in the United Arab Emirates. Interestingly, no article was found that primarily focused on addressing this aim, indicating an important knowledge gap. Accordingly, this review extrapolated relevant data from the

16 included articles that provided data on glycemic control in this population. From the literature obtained, baseline mean HbA1c levels in these studies ranged from 7.9% (63 mmol/mol) to 9.6% (81 mmol/mol). While many of the included articles have demonstrated improvements in glycemia, HbA1c remains suboptimal (> 7.0%, 53 mmol/mol) for the majority. This is consistent with findings internationally. Large databases such as the US T1D Exchange have shown children and teenagers have a mean HbA1c ranging from 9.1 to 10.3% (76–89 mmol/mol).[30] Similarly, the Australasian Diabetes Data Network have reported a mean HbA1c of 8.8% (1.8%), 72.2 mmol/mol (19.9 mmol/mol) among adolescents and young adults with a mean age of 18.5 years (2.3) with only 12.3% achieving the international target of < 7.0%, 53 mmol/mol HbA1c.[31] Looking closer at the Middle East, the SWEET diabetes database reported adjusted mean Hba1c of 9.5%, (80 mmol/mol) for children in Asia/Middle East/Africa.[32]

Diabetes technology has had positive clinical outcomes for children with type 1 diabetes. Further, diabetes education, provided in a targeted and structured manner and as part of the diabetes multidisciplinary team, was highlighted as fundamental to obtain positive outcomes. Additionally, with the increased use of diabetes technology comes additional education expectations from the diabetes team such as being able to use and interpret flash glucose monitoring or continuous glucose monitoring, and help with troubleshooting CSII therapy. In a review article that highlighted challenges in managing type 1 diabetes in toddlers, results included glycemic control challenges, dietary challenges, and psychosocial challenges.[33] The review concluded that provision of multidisciplinary teams with special expertise in managing pediatric type 1 diabetes, including psychological support, is essential.[33] The demands on diabetes teams are further extended to the month of Ramadan where some older children and teens will choose to fast. Avoiding hypoglycemia remains one of the main goals with Diabetes and Ramadan Guidelines (2021) recommending a reduction in basal insulin, especially in the fasting hours.[34] However, as seen in the current literature review, one study had conflicting results, with hypoglycemia occurring in both those who had their basal insulin doses reduced and those without reduction.[25] Local and international guidelines for health care professionals include clear preeducation assessment and education requirements, medication and glycemic target review, and follow-up that is critical to help support the patient to partake in fasting in a safe way.[34] While the studies reviewed demonstrated no significant deterioration in glycemia during Ramadan,[27,28] baseline glycemia prior to Ramadan was suboptimal with as many as 66% of teens commencing Ramadan fasting having a HbA1c > 8.0%, 64 mmol/mol.[28] As such, as part of the Diabetes and Ramadan Guidelines assessment and risk stratification process, all people with type 1 diabetes who intend to fast are usually classified as high risk and advised not to fast.[34] With the advancements in diabetes technologies and wider access to automated insulin delivery systems, this may change guidelines and how individuals with type 1 diabetes are risk-assessed in the future.

Despite suboptimal glycemic outcomes, it was shown that those utilizing CSII therapy had improved treatment satisfaction compared to those using MDIs. This highlights the need to ensure diabetes health care professionals adopt a patient-centric approach to managing diabetes. Diabetes distress was measured in only one study[22] and they too showed a high mean HbA1c of 9.6%, 81 mmol/mol, in their cohort, yet no statistically significant diabetes distress or depression was found in their participants with HbA1c < 7.5% versus those with > 7.5%, 58 mmol/mol. Their finding of females scoring significantly higher on depressive and diabetes distress scales compared to males potentially highlights the reality of stigma remaining rife especially within Emirati communities.[22] A case-based insight looked at United Arab Emirates Arab mothers' experiences at managing a child with newly diagnosed type 1 diabetes. Among the many fears they had, adverse judgments, including exclusion from being able to marry, was expressed, and they believed this would be directed toward their child because of this diagnosis.[35]

Limitations of our review should be acknowledged. All but one of the studies were based in Abu Dhabi, consistent with Shieb et al who identified that the Emirate of Abu Dhabi was responsible for 80.9% of research conducted between 2011 and 2015.[11] This may lead to less diversity within investigation sites and affect finding generalizability. Further, our review has also highlighted the small number of diabetes-related studies undertaken in the United Arab Emirates (14 out of 314), which focused purely on type 1 diabetes, and the relatively small number of studies targeting pediatric type 1 diabetes; mainly being on National Emirati children and youth, while the larger portion of the United Arab Emirates population is made of expatriates. However, strengths of our review are the number of databases searched and the methodology employed.

Conclusion

The glycemic control among children and adolescents in the United Arab Emirates is suboptimal and shown to range from HbA1c of 7.9% (63 mmol/mol) to 9.6% (81 mmol/mol). This will lead to unnecessary morbidity and mortality. With the increasing type 1 diabetes incidence and prevalence, diabetes-related technology will help people and/or carers to better manage and reduce the burden of living with this lifelong chronic condition, but research needs to be undertaken to ascertain how diabetes services are coping with these added tasks, how education is being provided to the users, and how reimbursement (if any) is occurring.

Structured diabetes education has no doubt been proven to help improve glycemic control, but not enough research is available on what is available in the United Arab Emirates for pediatric diabetes services. Access to health care professionals, frequency of visits, and reported clinical outcomes is not known or underreported. Furthermore, there is a lack of research on the area of mental health and type 1 diabetes, particularly in the pediatric population and that affects the carers. Stigma may be still to blame, and there is likely a lack of qualified health care professionals to refer to.

Research on diabetes and Ramadan in this population has shown no worsening of clinical outcomes during or after Ramadan compared to before Ramadan; however, the baseline HbA1c when starting the fasting period, showed suboptimal glycemic control, which did not improve throughout the month. This highlights the need for health care professionals to discuss risks and utilize local and international guidelines to help provide adequate assessment, education, and optimization of glycemia prior to fasting. Future studies should be aimed at investigating diabetes health services as well as shedding light on reimbursement, access to health care professionals, and the level of specialized skills in multidisciplinary teams.

Authors' Contributions

All authors played a vital role in the concept, design, gathering of data, analysis, write up, review, and editing of this manuscript. S.A., being the PhD student, was supported by her supervisors with weekly touch points to review every process and provide feedback and editing where needed. A.D. being the endocrinologist was also crucial to this manuscript as her views and insights regarding the data collection and analysis as well as review of the paper as a whole was a significant contributing factor.

Data Availability

Any additional data requested will be made available upon request.

Statement of Conformance to the Declaration of Helsinki

This study was conducted in full compliance with the ethical principles set forth in the Declaration of Helsinki. As the study did not involve human participants or personal data, ethics approval was not required.

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Conflict of Interest

S.A. works for Insulet Middle East and Developing Markets and declares that undertaking this literature review was independent of her work with the company. The other authors declare no conflict of interest.

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