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Recurrent education: A promising strategy for enhancing diabetes management and reducing hypoglycemia in children with type 1 diabetes

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Abstract

Background This study aimed to assess the impact of recurrent individualized education on the management of hypoglycemia, hypoglycemia awareness, and metabolic control of diabetes in children and adolescents living with type 1 diabetes (T1D).

Methods A prospective quantitative study involving participants aged 8 to 18 years with T1D was conducted. Three established hypoglycemia screening tools were employed: the Hypoglycemia Fear Survey (HFS), the Gold Hypoglycemia Awareness Questionnaire, and the Edinburgh Hypoglycemia Symptoms Scale. The participants used blinded continuous glucose monitoring (b-CGM) devices to document glucose values, meals, insulin doses, exercise periods, symptomatic hypoglycemia episodes, and glucose levels during hypoglycemia, experienced symptoms, and treatment approaches for hypoglycemia. Following this initial phase, the participants received education from healthcare professionals. The same procedures were repeated six weeks after the educational intervention.

Results Prior to education, approximately half ($n=21$) of the 47 participants were present with impaired hypoglycemia awareness (IHA), and half of the IHA group applied the appropriate hypoglycemia self-treatment. After education, almost all participants demonstrated an improved ability to manage hypoglycemia effectively. Following education, improvements in the frequency of fingerstick glucose measurement per day, time spent within the target glucose range (70–180 mg/dL), glycemic variability (GV), hypoglycemia perception, appropriate hypoglycemia self-treatment, and hypoglycemia fear were observed, both in participants with hypoglycemia awareness and those with IHA.

Conclusions The results indicate that children and adolescents living with T1D benefit from recurrent self-management education. The benefits were observed in both participants with hypoglycemia awareness and those with IHA. Education positively impacts diabetes management and enhances hypoglycemia awareness.

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Keywords Type 1 diabetes, Hypoglycemia unawareness, Diabetes self-management education, Fear of hypoglycemia.

Background

T1D occurs as a result of the autoimmune destruction of pancreatic beta cells. Due to this reason, insulin replacement therapy is obligatory for people living with T1D. Exogenous insulin does not take part in the physiological feedback loop. Therefore, it may induce hypoglycemia even if there is an intact counterregulatory mechanism [1]. Hypoglycemia is a commonly experienced acute complication of T1D that affects the quality of life and metabolic control of children and adolescents with diabetes, and their parents or caregivers [2].

Hypoglycemia and impaired awareness

Hypoglycemia is typically defined by a plasma glucose concentration below 70 mg/dL (3.9 mmol/L) [3]. The concentration of blood glucose lower than <54 mg/dL (3.0 mmol/L) is the threshold at which neuroglycopenic symptoms begin to occur and require immediate action to resolve the hypoglycemic event. A severe event due to hypoglycemia is marked by altered mental and physical functioning requiring external assistance, although it is not explicitly tied to glucose levels [4].

The main symptoms of hypoglycemia occur due to neuroglycopenia and autonomic activation [5]. As blood glucose levels decrease, activation of the autonomic nervous system leads to neurogenic symptoms, which facilitate the perception of hypoglycemia (hypoglycemia awareness) [6]. IHA is defined by the onset of neuroglycopenia before autonomic warning symptoms or as the failure to perceive a significant drop in blood glucose levels [7]. In individuals living with T1D, recurrent hypoglycemia has been shown to reduce the glucose level that precipitates the counter-regulatory response necessary to restore euglycemia during a subsequent episode of hypoglycemia [5–9].

Awareness of hypoglycemia is a significant factor in maintaining metabolic control and quality of life in people living with diabetes [6]. Individualswith T1D who have IHA and counterregulatory impairment are more likely to suffer from severe hypoglycemia, have a longer diabetes duration, have lower hemoglobin A1C (A1C) levels, and adrenergic symptom perception is either reduced or lost [5, 6]. It has been reported that attentive glucose monitoring, personalized blood glucose goals, and structured education programs are important in preventing and managing IHA [5–9]. Real-time continuous glucose monitoring (rtCGM) systems have been shown to reduce IHA and facilitate the measurement of intraday and interday glycemic differences in children and adolescents living with T1D [5, 9]. In the short term, GV reflects fluctuations in blood glucose levels throughout the day or between days, whereas in the longer term, it can indicate changes in long-term control markers such as A1C. Time in range (TIR) is the percentage of time spent between 70 and 180 mg/dL glucose level used to assess GV measurement. GV and TIR are clinically more meaningful in assessing daily glucose control and hypoglycemia risk than A1C [10].

Fear of hypoglycemia (FOH)

Despite improved diabetes technologies, FOH is a significant factor contributing to the impairment of metabolic control. One of the reasons adolescents living with T1D maintain high glucose levels is to avoid hypoglycemia, although they are adequately informed about diabetes management [11]. This fear leads to behaviors such as reducing insulin doses, frequent snacking, limiting daily activities, and excessive blood glucose monitoring [12].

Diabetes self-management education (DSME)

T1D is a life-long condition that requires ongoing management through lifestyle adjustments. It is crucial for individuals living with T1D to receive education that helps them adapt to manage this lifestyle effectively [13]. DSME is essential for the success of any intervention. The goals of DSME are to provide people living with T1D and their caregivers with the necessary information, reduce the risk of complications, and enhance their quality of life [14]. The primary focus of DSME is to support diabetes management by delivering essential information tailored to each patient's needs, thereby improving self-management skills. Structured education is beneficial for individuals living with T1D, as it reduces the frequency of severe hypoglycemia and the incidence of IHA [15].

This study includes children and adolescents living with T1D who attend a single diabetes center, aiming to address FOH and hypoglycemia unawareness and improve hypoglycemia management in this group. To achieve this goal, the effect of personalized and recurrent education on GV and TIR in children and adolescents with IHA was identified.

Research design and methods

Study participants

Children and adolescents living with T1D aged between 8 and 18 years and a duration of diabetes of at least five years who attended pediatric diabetes clinics at a university hospital in Istanbul, Türkiye, were eligible to participate in this prospective quantitative study. All patients had ongoing prospective documentation from diagnosis at 3-month intervals of hypoglycemic events, diabetes-related ketoacidosis, and glycemic control measured by A1C, and all of them were educated at the time of diagnosis as it is a standard procedure. The cases were selected from children and adolescents with diabetes who were on a regimen of multiple daily injections, had not used a continuous glucose monitoring (CGM) system, and had T1D for at least five years, regardless of their metabolic control. To analyze metabolic control levels more precisely, participants were grouped according to their A1C levels: <7% accepted as target range, 7≤…<9% accepted as suboptimal control, and ≥ 9% accepted as above target. All participants completed all study components, including the educational sessions, b-CGM wear periods, daily logs, and follow-up visits. In cases where data was missing or incomplete, participants were contacted for clarification, and these cases were documented in the data analysis process.

Procedures

During all the steps of this research, the Helsinki Declaration principles were followed by the research team and accepted before getting ethical approval. All the subjects consented to participate in the study, and a survey was conducted to collect general information, including whether they felt hypoglycemia, their weekly frequency of hypoglycemia, occurrences of severe hypoglycemia, incidents requiring glucagon, and the frequency of fingerstick glucose measurement per day. HFS was developed by Cox et al. to assess FOH in individuals with diabetes, and Erol and Enç evaluated its validity and reliability in the Turkish population. The survey comprises 32 items with two subscales (behavior and anxiety). The participants rated their FOH for each of the 32 items on a 5-point Likert-type scale ranging from 0 (never) to 4 (always), with total scores ranging from 0 to 128. There is no cutoff point; higher scores indicate a greater FOH [16]. IHA was assessed with the Gold Hypoglycemia Awareness Questionnaire, which was developed by Gold et al. and uses a simple 7-point Likert-type scale to answer the question "Can you perceive your hypoglycemia?" (1 = always aware of hypoglycemia, 7 = not aware of hypoglycemia at all) [17]. A score between 4 and 7 is consistent with the IHA. In our study, patients with a score of 4 or more were considered to have IHA. The Edinburgh Hypoglycemia Awareness Questionnaire, which was developed by McAulay et al., comprises 11 key symptoms (sweating, palpitations, shaking, hunger, confusion, drowsiness, odd behavior, speech difficulty, incoordination, nausea, and headache), which are evaluated on a 7-point Likert scale (from 1= "not at all" to 7= "very severe") and divided into 3 domains (neuroglycopenic, autonomic, and general malaise) [18, 19].

Before the beginning of education, a CGM device (Medtronic iPro®2, Northridge, USA) was applied to all participants by a trained diabetes care and education specialist for five days. The calibration of the b-CGM was performed according to the protocol outlined in the MiniMed CGM manual. Additionally, they completed the Gold Hypoglycemia Awareness Questionnaire and the Edinburgh Hypoglycemia Symptoms Scale to fill out during hypoglycemia events. All the subjects used the same brand of glucometer (Accu Chek Performa Nano, Roche Diagnostics, Germany) to record fingerstick-checked glucose levels and noted their symptoms, as well as treatments during hypoglycemia incidents. After this data was collected, the participants and their caregivers attended a two-hour education and evaluation session, which was repeated three times at weekly intervals.

At the time of diagnosis, all participants received standardized diabetes education from diabetes education nurses and dietitians specialized in diabetes care in the hospital's diabetes center. This initial education covered insulin therapy, carbohydrate counting, blood glucose monitoring, and hypoglycemia management. The same educators also conducted the recurrent education sessions in this study, ensuring consistency in teaching methodology and reinforcing key concepts.

The hypoglycemia education module was adapted from "The Education Guide for Diabetes Care and Education Specialists", published by the National Association of Pediatric Endocrinology and Diabetes under the Turkish Ministry of Health [20]. This module was delivered by the same registered nurses and dietitians who educated the patients and families at the time of diagnosis, ensuring continuity in educational content. Notably, this study used the same module at diagnosis and during the recurrent education sessions. The topics covered the hypoglycemia treatment algorithm, hypoglycemia symptoms, insulin therapy and application, hyperglycemia, carbohydrates that should/should not be used in hypoglycemia treatment, the importance of blood glucose monitoring and frequency, the exercise−hypoglycemia relationship, and hypoglycemia prevention methods. The participants underwent weekly outpatient check-ups and reported their blood glucose levels during this period. Weekly check-ups were conducted by diabetes education nurses, dietitians and pediatric endocrinologists at our center. Data collection, including b-CGM downloads and review of blood glucose logs, was performed by the same healthcare professionals to ensure consistency.

Six weeks after education, the participants used b-CGM for five days again, and the same procedures were repeated. In a notebook, participants and parents recorded blood glucose values, meals, insulin doses, exercise periods, and symptomatic hypoglycemia.

Table 1 Evaluation of descriptive variables according to the GOLD awareness scale

	GOLD Awareness Scale		*P*
	Hypoglycemia Aware Group (26)	**Group with IHA (21)**	
Age	15 (13–17)	13 (12-14.5)	**0.044**[1]
Gender*			
Male	11 (42.3)	7 (33.3)	0.529[2]
Female	15 (57.7)	14 (66.7)	
Weight SDS	0.58 (-0.82-1.16)	0.10 (-0.02-0.68)	0.392[1]
Height SDS	0.33 (-1.08-0.63)	0.22 (0.09–0.79)	0.398[1]
BMI SDS	0.14 (-0.79-0.95)	0.07 (-0.61-0.68)	0.653[1]
Age at Diagnosis	5 (3.8-7)	7 (4.5-9)	0.187[1]

[1]Mann Whitney U test, [2]Chi square test,

* in (%), others are shown as median (25-75th percentile)

At the end of the five days, the data was uploaded to the system and reviewed along with the data in the notebooks to determine glucose patterns. The collected data assessed hypoglycemia, unrecognized hypoglycemia, the percentage of time below range, and the time above range seen with b-CGM. Hypoglycemia was defined as a glucose level less than 70 mg/dL on the glucometer; participants notedsymptomatic hypoglycemia events and symptoms over five days, and their time was compared with b-CGM data.

A1C values were collected from the subject's medical records. A1c measurements were taken at the diabetes clinic using a Roche Cobas c513 analyzer (Germany).

Statistical analysis

Data analysis was performed via the SPSS 21 software package. The normality of continuous data was evaluated with Shapiro‒Wilk and Q‒Q plots. Continuous data that were not normally distributed are presented as medians (25th–75th percentiles), whereas categorical data are presented as frequencies and percentages. The Mann‒Whitney U test was used to compare continuous data between two independent groups, and the Wilcoxon test was used to compare two dependent groups before and after education. The chi-square and Fisher's exact tests were used for categorical data, and the McNemar test was used to compare two dependent groups before and after education.

Results

The study included 47 children, 29 girls and 18 boys whose average age was 13 ± 2.9 years, ranging from 8 to 18 years. The participants were divided into two groups: a hypoglycemia-aware group and a group with IHA, based on the Gold Hypoglycemia Awareness Questionnaire results measured before the education intervention. There was no significant difference between the two groups in terms of gender, weight SDS, height SDS, BMI SDS, or age at diabetes diagnosis ($p > 0.05$). However, the median age of the hypoglycemia-aware group (M = 15) was significantly greater than that of the group with IHA (M = 13) ($p = 0.044$) (Tables 1 and 2).

When the diabetes related clinical features of the hypoglycemia-aware group and group with IHA were compared, the A1C median was significantly greater in the hypoglycemia-aware group than in the group with IHA ($p = 0.016$). Metabolic control was likewise considerably worse in the hypoglycemia-aware group than in the group with IHA ($p = 0.022$). According to the Gold Hypoglycemia Awareness Questionnaire, the median hyperglycemia percentages were significantly lower in the group with IHA than in the aware group, whereas

Table 2 Evaluation of pre-education diabetes clinical characteristics according to the GOLD awareness scale

Pre-education	**GOLD Awareness Scale**		*P*
	Hypoglycemia Aware Group (26)	**Group with IHA (21)**	
A1C	7.9 (7.3–9.13)	7.2 (6.5–7.9)	**0.016**[1]
Metabolic control			
Target Range (< 7% A1C)	3 (11.5)	9 (42.9)	**0.022**[2]
Suboptimal Control (> 7…<9% A1C)	14 (53.8)	10 (47.6)	
Above Target (> 9% A1C)	9 (34.6)	2 (9.5)	
Daily insulin requirement	0.9 (0.8–1.2)	1 (0.79–1.1)	0.628[1]
Severe hypoglycemia experience	2 (7.7)	1 (4.8)	1.00[3]
Number of Glucagon use	4 (15.4)	0 (0)	0.117[3]
Frequency of fingerstick glucose measurement per day	5.5 (3–8)	7 (5-8.5)	0.090[1]
Number of hypoglycemic episodes with loss of consciousness requiring hospitalization	2 (7.7)	3 (14.3)	0.644[3]
Number of b-CGM hypoglycemia (< 70 mg/dl)	5 (3-7.3)	3 (1–5)	0.128[1]
Number of recorded fingerstick Hypoglycemia (< 70 mg/dl)	2 (0–3)	2 (1–4)	0.262[1]
TIR % (between 70 and 180 mg/dL)	42 (33-57.5)	52 (44-62.5)	0.95[1]
Time above range % (> 180 mg/dL)	51.5 (36-59.5)	37 (25-45.5)	**0.022**[1]
Time below range % (< 70 mg/dL)	4 (1.6.3)	8 (4.5–13.5)	**0.024**[1]
Hypoglycemia (< 70) hour/day	1.32 (0.24–3.48)	0.96 (0.24–1.92)	0.372[1]
The standard deviation of b-CGM values	49.5 (38-56.3)	50 (41–53)	0.797[1]
Average maximum of b-CGM values	157.5 (136.5-185.3)	174 (130-189.5)	0.872[1]
Perceiving hypoglycemia %	40 (15.6–69)	40.8 (21.3–67.8)	0.665[1]
Appropriate hypoglycemia self-treatment %	30 (0–95)	50 (16.7–68.3)	0.698[1]

[1]Mann Whitney U test, [2]Chi square test, [3]Fisher's exact test

* n(%), others are shown as median (25-75th percentile)

the hypoglycemia percentage was greater ($p = 0.022$ and $p = 0.024$, respectively). No significant differences were found in other metabolic or clinical features ($p > 0.05$) (Table 2).

Compared with their pre-education status, all participants experienced significant improvements in several areas after education: the frequency of fingerstick glucose measurement per day, the percentage of patients who perceived hypoglycemia, the percentage of appropriate hypoglycemia self-treatment (Appropriate hypoglycemia self-treatment was defined based on the guidelines from the National Association of Pediatric Endocrinology and Diabetes, which recommend the use of 15–20 g of fast- acting carbohydrates for hypoglycemia treatment, rechecking blood glucose after 15 min, and repeating treatment if needed.), and the duration of the study increased significantly ($p = 0.007$, $p = 0.006$, $p < 0.001$, and $p < 0.001$, respectively). Additionally, there was a significant decrease in the hyperglycemia percentage, hypoglycemia percentage, hypoglycemia hours per day, hypoglycemia FOH score, and median GV ($p < 0.001$, $p = 0.025$, $p = 0.025$, and $p < 0.001$, respectively). These results indicate that structured education significantly improved the participants' hypoglycemia management, awareness, and overall glycemic control (Table 3).

Significant improvements were observed in both groups when the effects of education on the hypoglycemia-aware group and the group with IHA were analyzed separately.

In children and adolescents with IHA, increases in TIR, proper treatment of hypoglycemia percentage, and A1C levels were noted ($p = 0.005$, $p = 0.007$, $p = 0.002$, respectively), whereas no significant changes were found

Table 3 Examination of diabetes clinical and metabolic characteristics before and after education

	Before the Education	**After the Education**	***P***
A1C	7.8 (7.1–8.4)	7.8 (7.2–8.3)	0.342[1]
A1C (Hypoglycemia Aware Group)	7.9 (6.4–11)	7.9 (6.3–9.7)	,223
A1C (Group with IHA)	7.2 (6.1–9.9)	7.8 (6.5–9.7)	**,002**
Metabolic control			
Target Range (< 7% A1C)	12 (25.5)	10 (21.3)	1.00[2]
Suboptimal Control (> 7…<9% A1C)	24 (51.1)	28 (59.6)	
Above Target (> 9% A1C)	11 (23.4)	9 (19.1)	
Frequency of fingerstick glucose measurement per day	6 (4–8)	8 (6–10)	**0.007**[1]
Number of b-CGM hypoglycemia (< 70 mg/dl)	4 (2–7)	3 (2–6)	0.348[1]
Number of recorded fingerstick Hypoglycemia (< 70 mg/dl)	2 (1–3)	2 (1–3)	0.723[1]
TIR (> 70…<180 mg/dL)	42 (31–54)	49 (37–59)	**< 0.001**[1]
TIR (Hypoglycemia Aware Group)	42 (14–93)	58 (19–90)	**,000**
TIR (Group with IHA)	52 (32–77)	67 (37–85)	**,005**
Hyperglycemia % (> 180 mg/dL)	42 (31–54)	37 (24–48)	**< 0.001**[1]
Hyperglycemia % (> 180 mg/dL) (Hypoglycemia Aware Group)	51.5 (6–88)	40.5 (7–78)	**,001**
Hyperglycemia % (> 180 mg/dL) (Group with IHA)	37 (17–66)	30 (12–62)	,070
Hypoglycemia % (< 70 mg/dL)	6 (2–9)	3 (1–6)	**0.025**[1]
Hypoglycemia (< 70 mg/dL) hour/day	1.2 (0.2–2.2)	0.7 (0.2–1.7)	**0.025**[1]
Hypoglycemia hour/day (Hypoglycemia Aware Group)	1,32 (0–12)	0.84 (0-3.6)	**,027**
Hypoglycemia hour/day (Group with IHA)	0.96 (0–7)	0,72 (0–2,16)	,418
Glycemic Variability	50 (39–55)	40 (35–45)	**0.001**[1]
Average maximum	163 (135–189)	156 (144–176)	0.505[1]
Perceiving hypoglycemia (< 70 mg/dL) %	40 (20–69)	60 (50–100)	**0.006**[1]
Appropriate hypoglycemia self-treatment %	50 (0–75)	100 (50–100)	**< 0.001**[1]
Appropriate hypoglycemia self-treatment % (Hypoglycemia Aware Group)	30 (0-100)	100 (0-100)	**,001**
Appropriate hypoglycemia self-treatment % (Group with IHA)	50 (0-100)	80 (20–100)	**,007**
HFS score	67 (59–79)	55 (48–67)	**< 0.001**[1]
GOLD Awareness*			
Hypoglycemia Aware Group	26 (55.3)	33 (70.2)	0.092[2]
Group with IHA	21 (44.7)	14 (29.8)	

[1]Wilcoxon test, [2]McNemar test

* in (%), others are shown as median (25-75th percentile)

in hyperglycemia percentage or hypoglycemia duration ($p > 0.05$).

In the hypoglycemia-aware group, increases in TIR and appropriate hypoglycemia self-treatment percentage were significant, alongside substantial reductions in hyperglycemia percentages and hypoglycemia durations ($p = 0.00$, $p = 0.001$, $p = 0.008$, 0.001, $p = 0.027$, respectively); however, no significant relationship was detected with A1C ($p > 0.05$) (Table 3). A moderate positive correlation existed between pre-education HFS scores and pre-education hyperglycemia percentage values and between post-education HFS scores and post-education hyperglycemia percentage values ($r = 0.346$, $r = 0.356$, respectively).

No significant correlations were detected with other metabolic or clinical features ($p > 0.05$) (Table 4).

When the symptoms experienced during hypoglycemia before and after education were compared, no significant difference was found between the pre and post-education scores ($p > 0.05$) (Fig. 1).

Discussion

This study revealed an association between recurrent educational sessions and improved diabetes management in children and adolescents living with TIR. Following these educational interventions, patients exhibited improvements in TIR, appropriate hypoglycemia self-treatment percentages, and FOH scores. Notably, although approximately half of the participants had IHA, all the groups benefited from education.

Previous studies have demonstrated that CGM use leads to improved glycemic control compared to self-monitoring of blood glucose in individuals living with T1D [21, 22]. However, not all children and adolescents living with T1D have access to CGM, particularly in low- and middle-income countries. As such, DSME remains essential for optimizing glycemic control in these populations.

Table 4 Evaluation of the relationship between HFS scores before and after education

	Pre-education HFS score		**Post-education HFS score**	
	R	**P**	**R**	**p**
Pre-education				
A1C	0.114	0.446	0.068	0.650
Appropriate hypoglycemia self-treatment %	0.065	0.703	-0.083	0.624
Time above range % (> 180 mg/dL)	**0.346**	**0.017**	0.284	0.053
Time below range % (< 70 mg/dL)	0.041	0.786	-0.183	0.217
Post-education				
A1C	-0.034	0.822	0.060	0.687
Appropriate hypoglycemia self-treatment %	0.131	0.415	-0.204	0.201
Hyperglycemia (> 180 mg/dL) %	0.154	0.300	**0.356**	**0.014**
Hypoglycemia (< 70 mg/dL) %	-0.052	0727	-0.212	0.153

A strength of our study is its comprehensive approach to analyzing the relationships between FOH, hypoglycemia management, and glycemic control and the effect of education on these factors in children and adolescents living with T1D. However, the short duration of follow-up is a limitation, as it restricts the ability to evaluate the long-term effects of recurrent education. Additionally, our study's other limitation is that the impact of the increased contact with patients on the above-mentioned improvements wasn't evaluated.

Recurrent hypoglycemia episodes can impair the awareness of hypoglycemia, which is crucial for appropriately treating hypoglycemia in its early stages. IHA increases the risk of severe hypoglycemia by more than five-fold [23]. Ly et al. reported that the mean age of patients with IHA was lower than that of patients with hypoglycemia awareness in their study of individuals aged six months to 19 years. Similarly, our study revealed that the median age of the hypoglycemia-aware group was 15 years, whereas the group with IHA had a median age of 13 years, which was a statistically significant difference ($p < 0.05$).

A1C is a marker used to monitor glycemic control [24]. Consistent with our findings, previous studies reported that participants with IHA had lower A1C levels and better metabolic control than did the hypoglycemia-aware group [23, 25, 26]. However, recent studies suggest that GV and TIR, when used together, provide a more comprehensive assessment of glycemic control than HbA1c alone, as they reflect real-time glucose fluctuations and time spent within the target range [27].

Lin et al. reported that adults with IHA experienced more hypoglycemia episodes despite the use of CGM [28].

Similarly, our study revealed lower hypoglycemia rates among hypoglycemia-aware children, but our study also revealed that this group had significantly higher hyperglycemia rates than children with IHA did.

A higher FOH might have caused excessive carbohydrate intake in daily diet and cases of hypoglycemia incidents for the hypoglycemia-aware group. Thus, this may be one of the reasons for the higher A1c levels observed in the hypoglycemia-aware group.

Zoysa et al. reported that hypoglycemia rates decreased while A1C levels remained unchanged at the 12-month follow-up after a 6-week-long education was given to 23 people living with T1D who had IHA [29]. Demir et al. reported that the duration of hypoglycemia decreased by 61% after nine children with IHA were educated out of a study group of 37 children living with T1D [30]. In our study of 47 children and adolescents living with T1D, 21 had IHA. Following the education of 47 subjects,

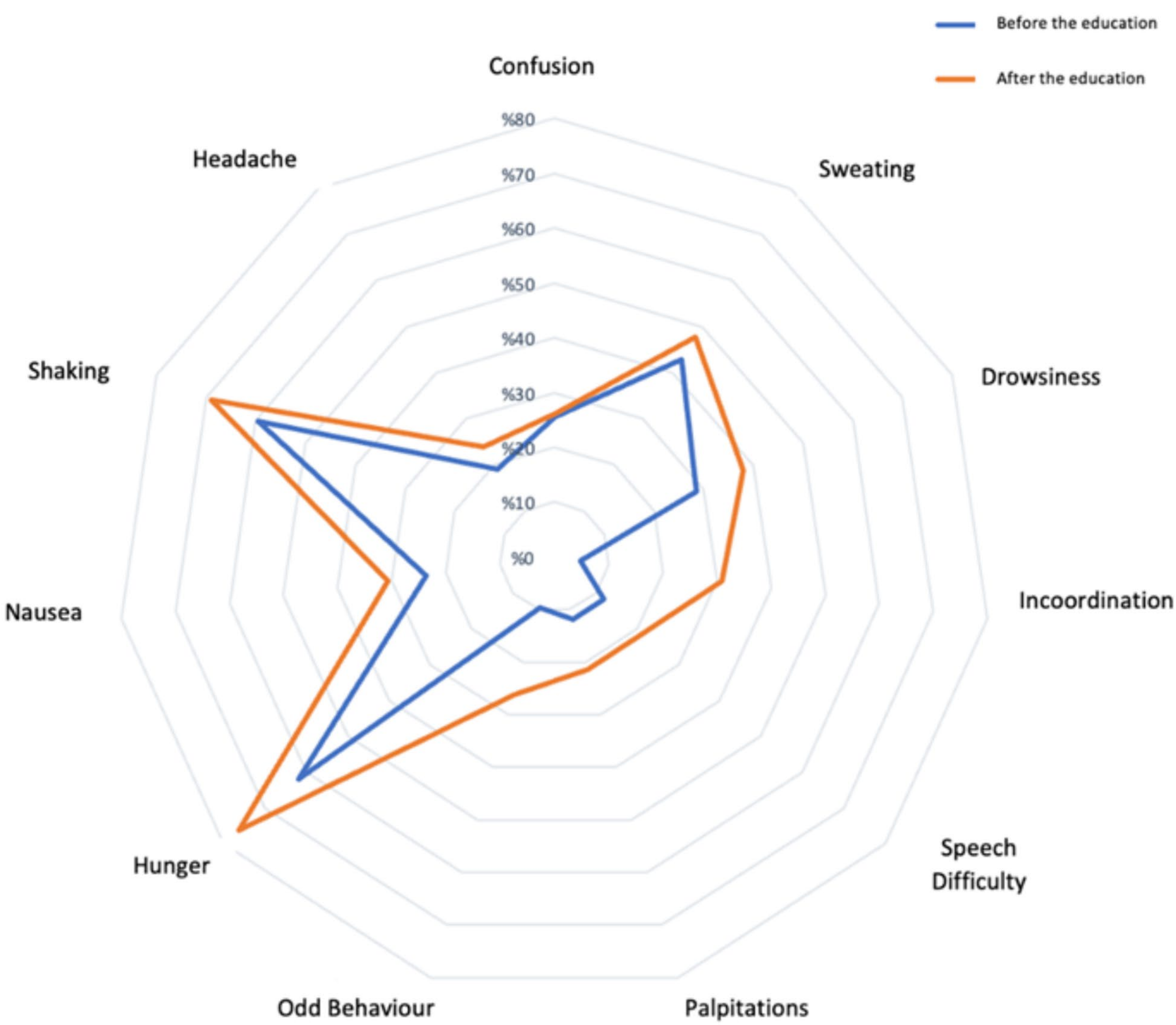

Fig. 1 Severity of perceiving hypoglycemia symptoms

hypoglycemia rates significantly decreased in the entire cohort. For the group with IHA, the TIR, appropriate hypoglycemia self-treatment percentage, and A1C levels increased. For the hypoglycemia-aware group, the TIR and proper hypoglycemia self-treatment rates significantly increased. Additionally, in both groups, the hypoglycemia and hyperglycemia rates significantly decreased. Similarly, Murata et al. reported that education reduced the duration of hypoglycemia in their study of 104 adults living with T1D [31].

A review by Iqbal et al. revealed that the effect of education on hypoglycemia management was such that the percentage of people living with T1D who perceived hypoglycemia increased with education [32]. Our study also revealed that the rate of hypoglycemia perception increased from 40 to 60% after education. Education also increased the frequency of fingerstick glucose measurement per day and the percentage of appropriate hypoglycemia self-treatment.

Tan et al., in their study of 96 people living with T1D who had a history of severe hypoglycemia or IHA, reported that GV can be improved with education, which is also consistent with our data [33].

FOH reduces the quality of life for people living with T1D, but education related to hypoglycemia may improve the quality of life by reducing FOH [34]. A review by Wild et al. reported that education may reduce FOH and improve diabetes management [35]. In our study, FOH scores also significantly decreased after recurrent education.

The relationship between A1C levels and HFS scores is controversial. Some studies suggest a correlation, whereas others do not. Our study did not observe a correlation between FOH scores and A1C levels.

Our study revealed that education for children and adolescents living with T1D can improve diabetes management by reducing FOH. Additionally, education decreases hypoglycemia rates and increases the percentage of perceiving hypoglycemia, TIR, and appropriate hypoglycemia self-treatment percentage in children and adolescents with IHA. Children and adolescents diagnosed with T1D are provided in-depth education about hypoglycemia at diagnosis. Our data indicate that recurring education by healthcare professionals is beneficial for both children and adolescents with IHA and those who are hypoglycemia-aware. In addition to DSME, technological advancements such as rtCGM and Automated Insulin Delivery (AID) systems play a crucial role in improving hypoglycemia awareness and prevention. rtCGM provides real-time glucose data and alerts, enabling early detection of hypoglycemia, while AID systems dynamically adjust insulin delivery to minimize glucose fluctuations [36, 37].

Although the potential benefits of recurrent education on diabetes management are exhibited in our study, further investigation is required. These include: [1] Investigation of long-term effects of recurrent education on diabetes management; [2] Standardization of the education amount and intervals; [3] Determining the effects of increased contact with healthcare professionals on diabetes management; [4] Integration of technologies like AID and rtCGM with educational interventions to further optimize glycemic control and hypoglycemia management.

Conclusions

Our findings highlight the beneficial effects of recurrent self-management education in patients living with T1D, particularly in improving appropriate hypoglycemia self-treatment, reducing hypoglycemia unawareness, enhancing diabetes management, and addressing FOH. Therefore, recurrent patient education is crucial for minimizing severe hypoglycemic episodes and mitigating avoidance behaviors associated with FOH.

Abbreviations

A1C	Hemoglobin A1c
b-CGM	Blinded Continuous Glucose Monitoring
CGM	Continuous Glucose Monitoring
rtCGM	Real-Time Continuous Glucose Monitoring
DSME	Diabetes Self-Management Education
FOH	Fear of Hypoglycemia
GV	Glycemic Variability
HFS	Hypoglycemia Fear Survey
IHA	Impaired Hypoglycemia Awareness
T1D	Type 1 Diabetes

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Author contributions

DGK: Ethical approval, author of results and conclusionEB: Study design and author of the methodHT: Author of introductionEK: Data collection and communication with participants, created tables andfigureGZE: Data collection and communication with participants, created referencesBZP: Statistical analysisOE: Author of discussion, research advisor.

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Data availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with Declaration of Helsinki and approved by The İstanbul University-Cerrahpaşa Clinical Sciences Ethics Committee (29430533-604.01-1178050). Written informed consent was obtained from all participants and their parents.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Clinical trial number

Not applicable.

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