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Received: 24 December 2021 | Revised: 16 May 2022 | Accepted: 7 June 2022

DOI: 10.1111/pedi.13381

ORIGINAL ARTICLE

ISPAD WILEY

An effective and cost-saving structured education program teaching dynamic glucose management strategies to a socio-economically deprived cohort with type 1 diabetes in a VIRTUAL setting

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Abstract

Objectives: Compare the clinical and cost-effectiveness of an established face to face (F2F) structured education program to a new remote (VIRTUAL) program teaching dynamic glucose management (DynamicGM) to children and young people with type 1 diabetes (CYPD) using continuous glucose monitoring (CGM). To ascertain the most effective DynamicGM strategies predicting time in range (TIR) (3.9–10.0 mmol/L) and incorporating these into a user-friendly teaching aid.

Design and methods: Effectiveness of the F2F and VIRTUAL programs were ascertained by comparing the mean change (Δ) from baseline to 6 months in HbA1c, TIR and severe hypoglycemia. Delivery cost for the two programs were evaluated. Factors predicting TIR in the combined cohort were determined and incorporated into a user-friendly infographic.

Results: First 50 graduates per group were evaluated. The mean difference in Δ HbA1c, Δ TIR and Δ episodes of severe hypoglycemia between VIRTUAL and F2F groups were 1.16 ($p = 0.47$), 0.76 ($p = 0.78$) and −0.06 ($p = 0.61$) respectively. Delivery cost per 50 CYPD for VIRTUAL and F2F were $5752 and $7020, respectively. The strongest predictors of TIR ($n = 100$) were short bursts of exercise (10–40 min) to lower hyperglycemia ($p < 0.001$), using trend arrow adjustment tools ($p < 0.001$) and adjusting pre-meal bolus timing based on trend arrows ($p < 0.01$). These strategies were translated into a GAME (Stop highs), SET (Stay in target), MATCH (Prevent lows) mnemonic.

Conclusion: Teaching DynamicGM VIRTUALLY is just as effective as F2F delivery and cost saving. Short bursts of exercise and using CGM trend arrows to adjust insulin dose and timing improves TIR.

KEYWORDS
CGMS, deprivation, diabetes, education, hypoglycemia, literacy

1 | INTRODUCTION

In children and young people with diabetes (CYPD) there is increasing emphasis on time spent in range (Time In Range, TIR [3.9–10.0 mmol/L or 70–180 mg/dl]) as opposed to the traditional gold standard of glycated hemoglobin or HbA1c. Availability of technologies such as continuous glucose monitoring (CGM) and flash glucose monitoring (FlashGM) have made this more achievable. However, to attain more than 70% TIR with less than 4% time below range (TBR [<3.9 mmol/L or <70 mg/dl])[1] CYPD must go beyond simple between-meal strategies

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such as insulin corrections for hyperglycemia[2] and set doses of 10–15 g fast-acting carbohydrates for hypoglycemia treatment.[3] Increased use of the emerging dynamic glucose management (DynamicGM) strategies will help CYPD achieve the above goals for TIR and hypoglycemia. The aim of using DynamicGM strategies is to minimize time above range (TAR [>10.0 mmol/L or >180 mg/dl]) and maximize TIR whilst preventing TBR.

1.1 | Minimizing TAR

The traditional strategy of using correction doses of insulin for hyperglycemia between meals is effective,[2] however, frequent review and correction of high glucose when using CGM/FlashGM risks stacking of insulin, and subsequent hypoglycemia.[4] An alternative effective strategy is to use activity to augment the action of insulin after a meal. Several studies have demonstrated that a 25%–75% reduction in prandial insulin prevents hypoglycemia when exercising for 30–60 min within 2 h of a meal.[5–7] Additionally, activity induces glucose uptake in the muscles independent of insulin action.[8] Between meal glucose lowering effect of activity has also been demonstrated in CYPD ($n = 50$) undertaking prolonged moderate intensity aerobic exercise after lunch with over half of them experiencing a drop of more than 2 mmol/L (36 mg/dl) within 15–30 min.[9] These findings were supported by another study reporting a glucose lowering effect of moderate intensity exercise in 93% of CYPD ($n = 112/120$) with an average decrease of 4.2 mmol/L (76 mg/dl) after 45 min.[10] The study also reported a significant inter-individual difference in response with a maximum fall in glucose of 13.6 mmol/L (257 mg/dl).[10] Both studies reported the greatest benefit in subjects with the highest glucose level at baseline.[9,10] Subjects starting with a blood glucose value higher than 10.5 mmol/L (190 mg/dl) had a median (quartiles) drop of 6.1 mmol/L (4.3, 8.9) or 110 mg/dl (78, 160) after 45 min with very few episodes of hypoglycemia.[10] Using exercise to treat hyperglycemia between meals also improves TIR.[11]

1.2 | Maximizing TIR

The benefit of pre-bolusing by 20 min before a meal is well-established[12]; however, there is no equivalent consensus on changing insulin timing or dose based on trend arrows. Teaching adjustment of mealtime insulin dose using the Trend Arrow Adjustment Tool (TAAT)[13] and altering pre-bolus timing based on glucose values and arrows have been reported to be associated with improved TIR.[11] However, neither strategies have a sufficiently established evidence base.

1.3 | Preventing TBR

Trend arrows and low alerts enable CGM/FlashGM users to prevent hypoglycemia. Previous teaching guides have proposed prevention of hypoglycemia by use of supplementary carbohydrates following algorithms based on glucose values and trend arrows, but altering the amount of carbohydrates has not been suggested.[14] The popular Sugar Surfing[15] method introduced the concept of consuming adjustable amounts of carbohydrate based on glucose value and fall rate. These guides and algorithms suggest using fast-acting carbohydrate but do not stipulate glucose only. The glycemic index of glucose is 100 compared to 70 for sucrose or sugar (glucose-fructose),[16] therefore, using sugar-based treatments such as jelly beans increases the frequency of double treatment.[17]

There is a dearth of structured education programs for CGM/FlashGM. SPECTRUM, a CGM structured education program,[18] has demonstrated improved diabetes knowledge and satisfaction at 6 months but not significantly improved HbA1c ($n = 120$).[19] We have previously reported the success of our structured education program, "The CGM Academy" on the first 50 CYPD demonstrating significant reduction in TBR by 8.3% ($p < 0.001$), HbA1c by 3.8 mmol/mol (0.3%, $p < 0.001$) and severe hypoglycaemic events from 10 to 1 ($p < 0.05$), while also improving TIR by 9.6% ($p < 0.001$) and quality of life ($p < 0.001$).[11] The use of DynamicGM strategies was the strongest predictor of TIR at 6 months ($p < 0.001$).[11] However, we did not scrutinize to assess the most powerful DynamicGM strategies from the seven individual strategies taught.[11] Teaching the most impactful strategies could prevent the risk of overwhelming users and carers, which is particularly important in population groups such as ours. Our population group has higher prevalence of socioeconomic deprivation, lower levels of education, lower income and significant barriers in language and understanding compared to the national average.[20] Moreover, reiteration of the most effective glucose management strategies in time restricted clinic consultations can ensure ongoing good glycemic control.

In March 2020, the COVID-19 pandemic required our center to move most clinical activities, including education to a virtual platform. A meta-analysis on the efficacy of web-based interventions for people with type 2 diabetes reported a 0.62% drop in HbA1c.[21] However, sub-analysis from another systematic review reported only a 0.1% reduction in HbA1c for people with type 1 diabetes using digital technologies aiming to improve self-management.[22] Blended programs using in-person and remote education have proven successful in people with type 1 diabetes,[23] however, studies comparing the two are lacking.[24] The unprecedented situation presented a unique opportunity to take The CGM Academy into the virtual era. We introduced flipped learning where educational material was provided beforehand for self-learning and the sessions with diabetes staff were used to deepen understanding[25]; a strategy which has proven to be more effective and time efficient than traditional teaching, not only in school classrooms[25] but also in chronic health conditions.[26] We report the efficacy and cost-effectiveness of the virtual program (VIRTUAL) compared to the original face to face program (F2F)[11] and also the strongest predictors of TIR. We present the user-friendly implementation tools which were developed to consolidate teaching of the most effective DynamicGM strategies.

2 | AIMS

1. Compare the clinical and cost effectiveness of teaching DynamicGM strategies by the established F2F CGM Academy[11] with VIRTUAL delivery using flipped learning.
2. Combine F2F and VIRTUAL data to ascertain the most effective DynamicGM strategies predicting TIR at 6 months and create a user friendly infographic incorporating these strategies.

2.1 | Outcome measures

- Change from baseline to 6 months in TBR2 (<3.0 mmol/L or <54 mg/dl), TBR, TIR, TAR, TAR2 (>13.9 mmol/L or 252 mg/dl), HbA1c mmol/mol, episodes of severe hypoglycemia requiring glucagon.
- Total cost of program delivery.
- The most effective DynamicGM strategies predicting TIR at 6 months.

As stipulated by the CGM funding body, the criteria to offer CGM included testing blood glucose eight or more times per day with at least one of the following documented hypoglycemia issues (a–e).

a. Severe hypoglycemia: one episode in the last 6 months requiring glucagon.
b. Asymptomatic hypoglycemia: more than two episodes of hypoglycemia (<4.0 mmol/L) per week without symptoms.
c. Impaired hypoglycemia awareness: more than two episodes of hypoglycemia (<3.0 mmol/L) per week without symptoms.
d. Nocturnal hypoglycemia: more than two episodes of hypoglycemia (<4.0 mmol/L) in the night per week.
e. Fear of hypoglycemia: Actively seeing a psychologist for fear of hypoglycemia.

3 | RESEARCH DESIGN AND METHODS

3.1 | Compare the clinical and cost effectiveness of F2F versus VIRTUAL structured education program

3.1.1 | Design and participants

The first 50 CYPD who graduated through the F2F CGM Academy and first 50 CYPD who graduated through the VIRTUAL program were prospectively studied.

3.1.2 | The CGM Academy education program

The design and development of the F2F CGM Academy and its contents are detailed in a previous report.[11] The F2F group were educated in groups of five from April 2019 to February 2020. Following the COVID-19 pandemic, from April 2020 onwards, the resources were moved to a digital platform. Dexcom G6 CGM was used by both F2F and VIRTUAL groups following a score of 29/30 on our previously reported CGM device selection criteria.[11]

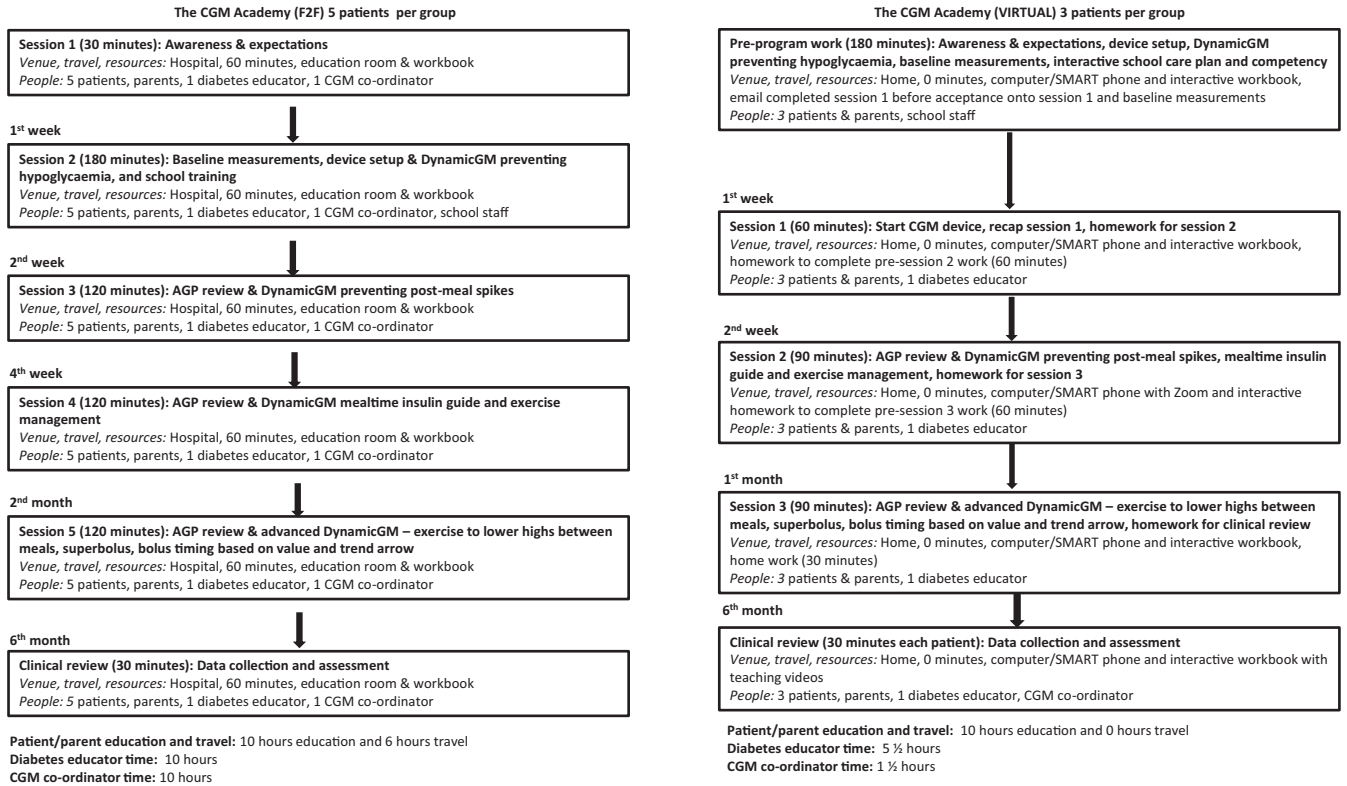

FIGURE 1 Structure of the Face to Face (F2F) and VIRTUAL CGM Academy

3.1.3 | VIRTUAL adaptation of the CGM academy

The workbook[11] was transformed into an interactive PDF using Adobe Acrobat DC license (cost $250). An editable personalized workbook was produced (by JP using JavaScript™ coding). Upon entering the name, weight and alert targets, the workbook automatically generates a personalized hypoglycemia treatment algorithm and exercise carbohydrate requirement based on the ISPAD CGM and exercise algorithms.[27] Over 30 video links of 5–10-min teachings by the diabetes team were incorporated into the workbook. All videos were hosted on www.screencast-o-matic.com (cost $180 annually). Similar approach was used to transform CGM school care plans into interactive PDFs with over 20 short videos that requires an 80% competency to pass, without the need for health care professional teaching time. Microsoft Teams™ already licensed by the Hospital Trust was used to conduct the sessions. All digital software packages were approved by the Hospital Trusts Clinical Governance Team.

The VIRTUAL program, based on flipped learning,[25] required the CYPD and/or their parents to complete pre-assessment work. Teaching sessions were reduced from five to three with shorter session times and delivered over a month instead of three with a clinical review at 6 months. The decision to truncate was based on user feedback from the F2F graduates who advised that the program was lengthy, and they preferred learning advanced strategies when their motivation was at its peak. Based on prior experience groups of three were felt to be ideal for virtual education deliver. The content and time commitments for F2F and VIRTUAL programs are detailed in Figure 1. In both programs, continued CGM funding was contingent on attending all education sessions and meeting a personalized goal for reduction in TBR set in the first session.

3.1.4 | Data collection

Data was collected from the online diabetes management database (TWINKLE). Data on age, duration of diabetes, postcode to determine quantile of socioeconomic deprivation,[20] therapy type (CSII or MDI), need for interpreter, HbA1c (mmol/mol), number of episodes of hypoglycemia requiring glucagon in the last 6 months and hypoglycemia indication for CGM were collected. Data submitted for approval of CGM was also collected and this included: the number of finger prick tests or FlashGM scans per day, percentage of readings TBR2, TBR, TIR, TAR and TAR2 over a 2-week period.

At 6 months, 2-week Dexcom data was collected on: CGM data capture percentage, percentage TBR2, TBR, TIR, TAR, TAR2, average daily low and high alarms, and Dexcom Followers. Number of severe episodes of hypoglycemia requiring glucagon in the last 6 months and HbA1c (mmol/mol) were collected from TWINKLE database.

3.1.5 | Cost analysis

Time taken to complete all administration tasks and deliver both the VIRTUAL and F2F CGM Academy were recorded by the CGM

BOX 1 The seven DynamicGM strategies taught in the CGM Academy

DynamicGM strategy	Description
1. Prevent hypos	Calculate hypoglycemia treatment using 3 g of carbohydrate per 10 kg prioritizing glucose treatment,[17] capping the weight calculation at 60 kg as the gastro-intestinal absorption of glucose is saturated at 1 g per minute.[38] Prevent hypoglycemia with fast acting carbohydrate when glucose level is 4.0–6.0 mmol/L (70–110 mg/dl) and falling, indicated by trend arrow.[14] Alter the amount of fast acting carbohydrate for preventing and treating hypoglycemia (<4.0 mmol/L) based on fall rate indicated by trend arrow.[39] Wait 20 min before re-treatment due to 5 min lag time between blood glucose and sensor glucose.[27]
2. Trend Arrow Adjustment Tool (TAAT)	Increase or decrease prandial insulin dose based on CGM trend arrow and insulin sensitivity factor.[13] The more aggressive the insulin sensitivity factor and the quicker the rate of glucose change, the greater the addition or subtraction from the prandial insulin dose.
3. Bolus timing	Adjust pre-prandial insulin timing based on glucose value and trend arrow. The algorithm is based on the usual 20 min wait[12] with extrapolations based on glucose value and trend-arrow.
4. Exercise checks	Consume fast acting carbohydrate before and every 20 min during exercise based on glucose value and trend arrow.[27]
5. Regular CGM report review	Review CGM download report weekly to assess DynamicGM usage and identify where therapy changes are needed.
6. Short burst of exercise	Choose a method of exercise (fast walking, jogging, jumping jacks etc) that can be performed almost anywhere. When the high alert sounds between meals, if practical, undertake a specified amount of exercise based on glucose value and trend arrow. Duration of exercise recommended is 10–40 min based on a 2.0 mmol/L (36 mg/dl) drop in glucose per 10–15 min of activity. This has been extrapolated from moderate intensity exercise studies showing a median (quartiles) drop of 6.1 mmol/L (4.3, 8.9) or 110 mg/dl (78, 160) with very few episodes of hypoglycemia in 45 min.[10]
7. Corrections	When the high alert sounds between meals, if not using short burst of exercise, administer the correction dose recommended.

Abbreviation: CGM, continuous glucose monitoring.

Coordinator. The CGM Coordinator, paid at Band 4 National Health Service (NHS) $15 per hour,[28] completed all the administration tasks including invite letters, phone calls, emails, funding applications, resource ordering and audit data collection. A specialist diabetes nurse or dietitian, paid at Band 6 or 7 NHS $ 21–26 per hour,[28] lead all the CGM Academy sessions. The CGM Coordinator support to deliver the CGM Academy sessions was required for F2F but not the VIRTUAL program. The cost of lesson plans and physical/digital workbook development was calculated using Band 7 NHS $26 hourly rate[28] for dietitian or nurse time, and Band 4 NHS $15 hourly rate[28] for graphic designer time. Each printed workbook cost $7 and the cost of interpreter was $15 per hour.[28]

3.2 | Ascertain the most effective DynamicGM strategies predicting TIR at 6 months and create user friendly infographics

The seven DynamicGM strategies (Box 1) taught included (1) Prevent hypos (2) TAAT (3) Bolus timing (4) Exercise checks (5) Regular CGM report review (6) Short bursts of exercise and (7) Insulin Corrections. A DynamicGM score[11] was developed to assess the implementation of DynamicGM by users. DynamicGM score was derived from the seven DynamicGM strategies, each with a score of 0–4 (0 = not proactive, 4 = very proactive) allowing for the lowest score of 0 for the least proactive and highest of 28 for the most proactive users. Box 2 details the seven questions and the scoring system. In addition to the DynamicGM score at 6 months the questionnaire also gathered data on the number of daily Dexcom checks by the CYPD and parent/guardian.

Data from the F2F and VIRTUAL groups were combined and analyzed to ascertain the strongest predictors of TIR at 6 months. Qualitative assessment through a questionnaire and informal feedback was sought at the 6-month review on the taught program and teaching materials from all CYPD and families. The feedback was combined with the strongest predictors of TIR determined to condense teaching material. There was a focus on using infographics due to their known effectiveness in teaching complex concepts.[29] All CGM Academy graduates were invited to critically appraise the new materials. Ten of the hundred families who agreed to participate provided feedback, novel suggestions for the infographic and final ratification.

3.2.1 | Statistical analysis

Descriptive statistics were used to report the baseline characteristics and are presented as mean and standard deviation (SD) for the continuous scale variables and as frequency and percent for categorical variables. The mean change in outcome measures from baseline to 6 months are presented as delta (Δ). The baseline characteristics are compared using independent sample t-tests for the continuous scale variables and the chi-squared tests for the categorical variables between the F2F and VIRTUAL groups. The mean change Δ in outcome measures for F2F to VIRTUAL programs were compared using an independent sample *t*-test and are reported as mean difference with 95% confidence intervals (95% CI).

The correlation between DynamicGM score and TIR was assessed using spearman's correlation. Factors predicting TIR were identified using multiple linear regression at a significance level of $p < 0.05$. In addition to the seven DynamicGM strategies, the following factors were included in the model: daily Dexcom checks, low alarms, high alarms, and number of Dexcom Followers. The control variables were glucose monitoring type at initiation (FlashGM vs. finger prick), reason for initiation of Dexcom, duration of diabetes, presence of severe

BOX 2 DynamicGM strategy scoring system, where 0 indicates not proactive and 4 very proactive, allowing for a minimum score of 0 and maximum of 28[11]

DynamicGM strategies	0 points	1 point	2 points	3 points	4 points
1: *Prevent hypos*: How many times a week do you use the trend arrows to prevent hypos?	0	1–5	6–10	11–15	16–20
2: *TAAT*: How often do you change meal-time insulin doses based on the trend arrows?	Never	Sometimes	Half	Most	All
3: *Bolus timing*: How many minutes before a meal would you give insulin if the CGM showed 10–14 mmol/L and was rising?	0–10	11–20	21–30	31–40	41–50
4: *Exercise checks*: How frequently do you check your CGM during exercise?	Never	60 min	30 min	20 min	10 min
5: *Regular CGM report review*: How often do you review your download to support your diabetes management?	12 weeks	8 weeks	4 weeks	2 weeks	Weekly
6: *Short bursts of exercise*: How many minutes exercise would you do to bring glucose back down if it is 10-14 mmol/L and rising?	0	5	10	15	20
7: *Corrections*: How long after eating do you usually wait before correcting a high glucose level?	Do not correct	4 h	3 h	2 h	1 h

Abbreviation: CGM, continuous glucose monitoring.

hypoglycemia before Dexcom and percentage CGM data capture. All analyses were performed using SPSS statistical software v26.0.

3.3 | Ethics

The above work was undertaken as part of our service development, delivery and evaluation. The project was approved as service development by our institution's audit committee.

4 | RESULTS

Detailed patient characteristics for both F2F and VIRTUAL groups are presented in Table 1. The mean ± SD age of the F2F cohort (10.23 ± 4.47 years, $n = 50$) was lower than the VIRTUAL cohort (13.16 ± 4.01 years, $n = 50$; $p < 0.001$). The F2F group had more insulin pump users (68%) when compared to the VIRTUAL group (42%, $p = 0.009$). The F2F group had less TBR2 at baseline (3.20% ±1.5) than the VIRTUAL Group (4.05% ±1.89, $p < 0.01$). There were no other significant differences between groups at baseline including level of social deprivation, reason for CGM initiation, HbA1c, TBR, TIR, TAR, TAR2 and episodes of severe hypoglycemia. The majority of the cohort were from the two most deprived socioeconomic quintiles (62% in F2F and 66% in VIRTUAL groups).

4.1 | Clinical effectiveness of F2F versus VIRTUAL program

There was no significant difference in the mean Δ TBR, Δ TIR, Δ TAR, Δ HbA1c and Δ episodes of severe hypoglycemia between the F2F

TABLE 1 Patient characteristics at baseline in Face to Face and VIRTUAL groups

	Face-to-Face (F2F)		VIRTUAL		Total		
Characteristic	**Sample size, *n***	**Value (SD)**	**Sample size, *n***	**Value (SD)**	**Sample size, *n***	**Value (SD)**	**p-Value**
Age (years)	50	10.23 (4.47)	50	13.16 (4.01)	100	11.70 (4.48)	**<0.001**
Duration of diabetes (Years)	50	5.15 (3.66)	50	5.70 (3.85)	100	5.43 (3.75)	0.476
HbA1c (mmol/mol)	50	57.56 (9.13)	50	60.52 (11.15)	100	59.04 (10.29)	0.151
Interpreter	4	8.0%	3	8.0%	7	7.0%	0.727
Therapy type							**<0.01**
MDI	16	32.0%	29	58.0%	45	45.0%	
Insulin pump	34	68.0%	21	42.0%	55	55.0%	
Glucose monitoring before CGM							0.476
Blood glucose	37	74.0%	40	80.0%	77	77.0%	
CGM	13	26.0%	10	20.0%	23	23.0%	
Multiple index of deprivation							0.966
Most deprived	23	46.0%	25	50.0%	48	48.0%	
Second most deprived	8	16.0%	8	16.0%	16	16.0%	
Third most deprived	12	24.0%	10	20.0%	22	22.0%	
Second least deprived	5	10.0%	4	8.0%	9	9.0%	
Least deprived	2	4.0%	3	6.0%	5	5.0%	
Reason for CGM initiation							0.981
Severe hypoglycemia	4	8.0%	2	4.0%	5	5.0%	
Asymptomatic hypoglycemia	14	28.0%	12	24.0%	26	26.0%	
Impaired hypoglycemia Awareness	25	50.0%	29	58.0%	54	54.0%	
Nocturnal hypoglycemia	1	2.0%	1	2.0%	2	2.0%	
Under 5 years of age	5	10.0%	5	10.0%	11	11.0%	
Fear of hypoglycemia	1	2.0%	1	2.0%	2	2.0%	
Percentage of glucose readings							
TBR2: <3.0 mmol/L (54 mg/dl)	50	3.20 (1.51)	50	4.05 (1.89)	100	3.62 (1.75)	**<0.05**
TBR: <3.9 mmol/L (70 mg/dl)	50	10.43 (5.11)	50	11.19 (4.91)	100	10.81 (5.00)	0.448
TIR: 3.9–10.0 mmol/L (70-180 mg/dl)	50	47.35 (9.79)	50	50.47 (11.69)	100	48.91 (10.84)	0.152
TAR: >10.0 mmol/L (>180 mg/dl)	50	42.22 (1.33)	50	38.17 (12.48)	100	40.20 (12.03)	0.093
TAR2: >13.9 mmol/L (252 mg/dl)	50	14.12 (3.74)	50	12.68 (5.22)	100	13.4 (4.58)	0.118
Episodes of severe hypoglycemia	50	0.20 (0.70)	50	0.14 (0.57)	100	0.17 (0.64)	0.640

Note: The bold values in this table represent statistically significant.

and VIRTUAL groups (Table 2). The mean Δ TAR2 in the F2F group (−6.81) was greater when compared to the VIRTUAL group (−2.01) [mean difference 2.4, 95% CI (7.17, 2.44), $p < 0.001$]. Δ TBR2 in the VIRTUAL group (−3.62) was greater than the F2F group (−2.83) [mean difference 0.79, 95% CI (0.11, 1.47), $p < 0.05$] (Table 2). The outcomes at 6 months in VIRTUAL group mirror the results in the F2F group with no significant differences in TBR, TIR, TAR, HbA1c and episodes of severe hypoglycemia (Table 3). From baseline to 6 months, the percentage of subjects achieving ≥70% TIR increased from 10% ($n = 5$) to 20% ($n = 10$) for the F2F group and 2% ($n = 1$) to 18% ($n = 9$) for the VIRTUAL group.

4.2 | Cost effectiveness of F2F versus VIRTUAL program

The F2F program had 100% attendance and the VIRTUAL program 97%, with five CYPD missing session 3 of the VIRTUAL program which were delivered later. Table 4 details the direct cost comparison of the F2F versus VIRTUAL CGM Academy. Nine F2F groups educated 45 CYPD at the cost of $5085 versus 15 VIRTUAL groups that educated 45 CYPD at a cost of $3585. The additional session for the VIRTUAL program cost $173. CYPD requiring an interpreter had a diabetes educator present for all sessions. Four CYPD required an interpreter for the F2F program at a cost of $1668 and three CYPD for the VIRTUAL program at a cost of $1251. One CYPD had significant psychosocial issues requiring one to one education for the F2F program costing $267 and two CYPD for the VIRTUAL program at the cost of $313. The total education cost was $7020 and $5752 (including $430 annual license fees) respectively for 50 CYPD educated by the F2F and VIRTUAL program respectively, with an 18% difference and $1268 saving per 50 CYPD educated in the VIRTUAL group. Diabetes educator time reduced from 150 h for the F2F program to 124 h for the VIRTUAL program. Learning time remained constant at 10 h per CYPD for both programs, with 5.5 of the 10 h being self-directed learning for the VIRTUAL group. The indirect costs could not be quantified. The estimated travel time for each family for the F2F program was 1 h per session, totalling to 300 hours. The F2F program required six half days for each CYPD, totalling 900 school learning hours missed and an unknown amount of parental work time or annual leave lost. The VIRTUAL sessions were scheduled after 3.30 pm to avoid school absence and minimize parental time off work.

TABLE 2 Comparison of outcome measures between Face-to-Face and VIRTUAL groups at baseline and 6 months after CGM initiation and structured education

	Face-to-Face (F2F)			VIRTUAL				95% CI		
	N	Mean Δ	Std. dev	N	Mean Δ	Std. dev	Mean Diff	Lower	Upper	*p*-Value
HbA1c	50	−3.80	6.58	50	−4.96	9.20	1.16	−2.01	4.33	0.470
Percentage of glucose readings										
TBR2: <3.0 mmol/L (54 mg/dl)	50	−2.83	1.51	50	−3.62	1.89	0.79	0.11	1.47	**<0.05**
TBR: <3.9 mmol/L (70 mg/dl)	50	−8.33	5.25	50	−9.19	5.17	0.85	−1.21	2.92	0.414
TIR: 3.9–10.0 mmol/L (70–180 mg/dl)	50	9.68	12.09	50	8.93	14.72	0.76	−4.59	6.10	0.780
TAR: >10.0 mmol/L (>180 mg/dl)	50	−1.92	15.27	50	0.23	16.25	−2.16	−8.41	4.10	0.495
TAR2: >13.9 mmol/L (252 mg/dl)	50	−6.81	4.17	50	−2.01	7.34	−4.81	−7.17	−2.44	**<0.001**
Episodes of severe hypoglycemia	50	−0.18	0.66	50	−0.12	0.52	−0.06	−0.30	0.18	0.615

Note: The bold values in this table represent statistically significant.
Abbreviation: CGM, continuous glucose monitoring.

TABLE 3 Comparison of outcome measures between Face-to-Face and VIRTUAL groups 6 months after CGM initiation and structured education

	Face-to-Face			Online				95% CI		
	N	Mean	Std. dev	*N*	Mean	Std. dev	Mean diff	Lower	Upper	*p*-Value
HbA1c	50	53.76	7.04	50	55.56	6.66	−1.80	−4.52	0.92	0.192
Percentage of glucose readings										
TBR2: <3.0 mmol/L (54 mg/dl)	50	0.37	0.42	50	0.43	0.46	−0.06	−0.23	0.12	0.510
TBR: <3.9 mmol/L (70 mg/dl)	50	2.10	1.64	50	2.01	1.58	0.09	−0.55	0.73	0.780
TIR: 3.9–10.0 mmol/L (70–180 mg/dl)	50	57.04	11.99	50	59.39	12.24	−2.36	−7.17	2.45	0.333
TAR: >10.0 mmol/L (>180 mg/dl)	50	40.29	12.93	50	38.41	12.77	1.88	−3.22	6.98	0.465
TAR2: >13.9 mmol/L (252 mg/dl)	50	7.30	2.46	50	10.67	6.56	−3.37	−5.34	−1.41	**<0.001**
Episodes of severe hypoglycemia	50	0.02	0.14	50	0.02	0.14	0.00	−0.06	0.06	1.000

Note: The bold values in this table represent statistically significant.
Abbreviation: CGM, continuous glucose monitoring.

TABLE 4 Cost analysis and comparison of CGM Academy delivery Face to Face (F2F) versus VIRTUAL

CGM Academy delivery requirements	F2F Per 5 CYP	VIRTUAL Per 3 CYP (change from F2F)	F2F Per CYP	VIRTUAL Per CYP (change from F2F)	F2F CYP with interpreter	VIRTUAL CYP with interpreter (change from F2F)	F2F CYP with psycho-social needs	VIRTUAL CYP with psycho-social needs (change from F2F)
Administration at $15 per hour	$150	$90 (−$60)	$30	$30 (−$0)	$30	$30 (−$0)	$30	$30 (−$0)
Resource cost of $7 per workbook	$35	$0 (−$35)	$7	$0 (−$7)	$7	$7 (−$0)	$7	$0 (−$7)
CGM Co-ordinator education at $15 per hour	$150	$22.5 (−$127.5)	$30	$7.5 (−$22.5)	N/A	N/A	N/A	N/A
Diabetes educator education at average $23 per hour	$230	$126.5 (−$103.5)	$46	$42 (−$4)	$230	$230 (−$0)	$230	$126.5 (−$103.5)
Interpreter at $15 per hour	N/A	N/A	N/A	N/A	$150	$150 (−$0)	N/A	N/A
Total cost	$565	$239 (−$326)	$113	$79.5 (−$63.5)	$417	$417 (−$0)	$267	$156.5 (−$110.5)

Abbreviation: CGM, continuous glucose monitoring.

TABLE 5 Linear regression results assessing factors influencing TIR

	Coefficient	95% CI		*p*-Value
		Lower	Upper	
Predictors				
Short burst exercise	3.261	2.093	4.428	**<0.001**
TAAT	3.085	1.622	4.548	**<0.001**
Bolus timing	2.651	0.785	4.518	**<0.01**
Daily Dexcom low alarms	1.353	0.373	2.333	**<0.01**
Daily Dexcom high alarms	−1.338	−2.346	−0.329	**<0.01**
Prevent hypos	2.52	0.494	4.545	**<0.05**
Regular CGM report review	1.341	0.05	2.632	**<0.05**
Corrections	1.395	0.042	2.748	**<0.05**
Number of Dexcom followers	1.171	−0.112	2.454	0.073
Exercise checks	1.137	−0.147	2.422	0.082
Daily Dexcom checks	0.013	−0.123	0.15	0.846

Note: The bold values in this table represent statistically significant.
Abbreviations: CGM, continuous glucose monitoring; TIR, time in range.

4.3 | Predictors of TIR at 6 months

There was a statistically significant linear relationship between TIR and the DynamicGM score ($r = 0.57$, $p < 0.01$). The results of the linear regression for TIR are presented in Table 5. The best predictors for TIR were: Short bursts of exercise ($\beta = 3.261$, $p < 0.001$), TAAT ($\beta = 3.085$, $p < 0.001$), Bolus timing ($\beta = 2.651$, $p < 0.01$), Prevent hypos ($\beta = 2.52$, $p < 0.05$), Daily Dexcom low alarms ($\beta = 1.353$, $p < 0.01$) and Daily Dexcom high alarms ($\beta = -1.338$, $p < 0.01$). Regular CGM report review ($\beta = 1.341$, $p < 0.05$) and Corrections ($\beta = 1.395$, $p < 0.05$) were also significant predictors. No relationship was found with number of Dexcom followers ($\beta = 1.171$, $p = 0.073$), Exercise checks ($\beta = 1.137$, $p = 0.082$) and daily Dexcom checks ($\beta = 0.013$, $p = 0.846$).

4.4 | Develop user friendly infographics using strongest predictors of TIR and user feedback

At the 6 month review, the majority of the cohort reported the need for summary materials consolidating the learning for quick review of

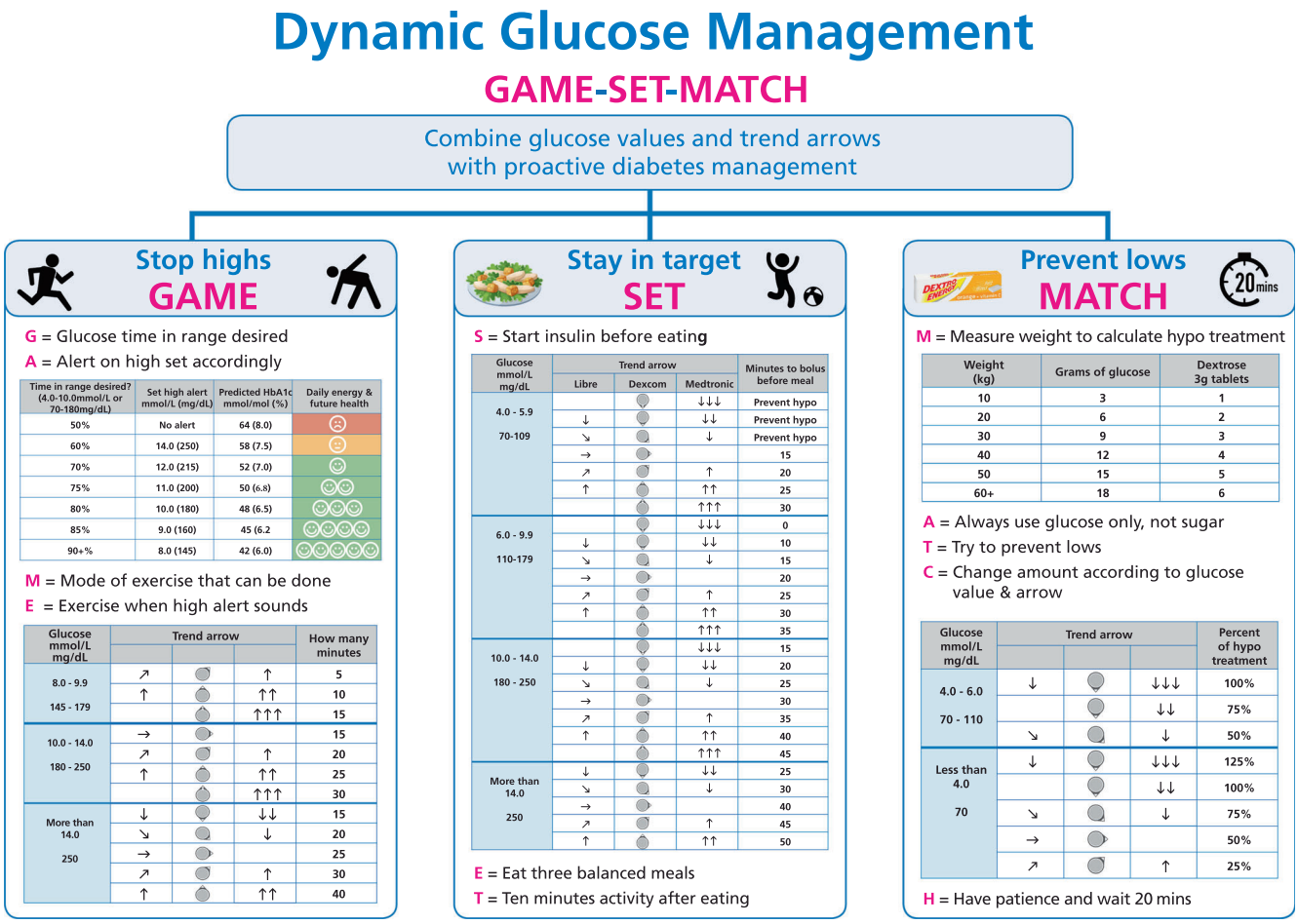

FIGURE 2 GAME-SET-MATCH mnemonic infographic teaching effective dynamic glucose management strategies

key information. Hence, an infographic was created after combining the strongest predictors of TIR and users' feedback, which were ultimately critically appraised and approved by 10 families.

The infographic and teaching material (Figure 2 and Figures S1 and S2) puts DynamicGM into three categories with a mnemonic for each category for easy retention, GAME-SET-MATCH.

5 | DISCUSSION

To our knowledge, this is the first real world report of a pediatric CGM structured education program, outside of research trials, demonstrating significant improvements in glycaemic control and also quality of life which we have previously reported.[11] We demonstrate that teaching DynamicGM strategies virtually to CYPD experiencing hypoglycemia issues using flipped learning is cost-saving and clinically just as effective as face to face teaching.[11] Teasing out the most effective strategies to improve TIR such as short bursts of exercise, using TAAT, adjusting pre-bolus timing and tailored hypoglycemia treatment; and incorporating these into a visual teaching aid can ease implementation of complex concepts.

Health literacy is closely linked to digital literacy and with the new global COVID-19 pandemic, digital delivery of healthcare is a priority.[30] Clinically effective and proven structured education programs which can be delivered virtually can lead to more effective use of healthcare staff time, resources and can be made widely available. Despite the high levels of socioeconomic deprivation in our cohort, which is closely linked to poor digital literacy,[31] our VIRTUAL program has proven to be effective and comparable to the F2F program in improving HbA1c, TIR and episodes of severe hypoglycemia. In comparison to the F2F group, the VIRTUAL group had a superior reduction in TBR2, likely due to the higher percentage of TBR2 at baseline and an inferior improvement in TAR2 likely due to the higher average age in the VIRTUAL group. In our experience, teenagers are less likely to employ DynamicGM strategies such as short bursts of exercise to minimize hyperglycemia, as in real-life this approach may be less desirable or practical. The VIRTUAL program is 18% cheaper than the F2F program and most importantly has meaningful benefits for CYPD and their families due to reduced time off school/work and travel.

Currently, there are no established structured education programs in CYPD with clinically proven benefit on HbA1c. The SPECTRUM CGM program for adults and CYPD[18] reports an improvement in adult CGM specific knowledge but not HbA1c.[19] Making attendance of all education sessions and achieving a personalized reduction in TBR

essential for ongoing funding may explain the improved HbA1c in this cohort. Improving TIR extends beyond frequency of checking and includes proactive use of DynamicGM strategies. Further interrogation of the seven DynamicGM strategies taught, to prioritize the most effective strategies, identified Short bursts of exercise, TAAT, Bolus timing and Prevent hypoglycemia to be the most significant factors in addition to the known benefit of glucose alarms.

Short 10–40-min bursts of moderate intensity activity such as fast walking to lower hyperglycemia between meals is strongly associated with improved TIR. In comparison, early intervention with a corrective insulin between meals is not as strongly associated. Rapid -acting insulin typically peaks at 90–120 min with a 300–360 min duration of action,[32] whereas exercise augments the potency of previously administered insulin in lowering glucose between meals much faster by expediting insulin absorption,[27] increasing blood flow to the muscles[33] and slowing hepatic and renal degradation of insulin through reduced blood flow.[34] Corroborating this idea of attenuation in clearance, exercise has been shown to maintain serum insulin concentrations during 1 h of exercise performed 90 minutes after delivering prandial insulin,[35] when serum insulin concentration would be expected to fall.[32] Also, activity induces muscle GLUT-4 translocation independent of insulin that increases glucose uptake in the absence of prandial insulin.[8] Given the multiple physiological mechanisms involved in lowering glucose, CYPD who use short bursts of exercise when feasible achieve better TIR. Although all CYPD will not implement short bursts of exercise, it is a potent alternative to corrective insulin doses for those who choose to, and it is important for clinicians to emphasis on these strategies. Exercise also potentially lowers the total daily insulin dose which has added health benefits. The DCCT/EDIC data have demonstrated that higher insulin doses are associated with adverse trends in several cardiometabolic disease risk factors.[36]

We found that frequent use of the TAAT to alter prandial insulin doses improved TIR, adding further real-world evidence to the existing literature.[13] Similarly, adjusting pre-meal insulin timing based on glucose value and trend arrow also improved TIR. The value of pre-bolusing by 20 min is ingrained,[12] however considering pre-meal glucose value and trend arrows is not as well-established, possibly due to the unavailability of trend data in non-CGM users. With increasing use of CGM, it is crucial to teach glucose management strategies that consider the trend arrow. Combining weight-based hypoglycemia treatment[17] with an adjustment protocol based on the glucose value trend arrow is not only predictive of TIR but also avoids over-shooting target glucose unnecessarily. Glucose only options for hypoglycemia prevention and treatments are strongly recommended given the fast glycemic response[16] and reduced risk of prolonged hypoglycemia and the need for double treatment.[17]

Whilst the above strategies have proven to be most effective, employing all these strategies may overwhelm the CYPD and families, especially in the setting of lower levels of numeracy and literacy. Therefore, we created two infographics with user feedback to simplify the complex DynamicGM strategies and mealtime insulin dosing. Moving forward DynamicGM strategies will be taught in lay language with mnemonics to facilitate memory retention; Stop highs (GAME), Stay in Target (SET), and Prevent Lows (MATCH), (Figure 2). The DynamicGM strategies for GAME and MATCH were clear from the regression analysis showing the benefit of using short bursts of exercise to lower hyperglycemia and tailored glucose treatments to prevent hypoglycemia. GAME requires the user to identify a target TIR in order to achieve a specific HbA1c result,[37] set the high alert accordingly, and take corrective action in response to the alert. We suggest starting the high alert at 12.0–14.0 mmol/L (216–252 mg/dl) and gradually lower as TIR improves, to prevent alarm fatigue at the outset. Progressively lowering of the high alert may improve TAR for future cohorts. Both TAAT and bolus timing were viable options for SET and users indicated that the majority preferred to adjust bolus timing as it was simple to follow and could be implemented by other caregivers. All GAME-SET-MATCH strategies require a careful trial and error approach and may occasionally cause hypoglycemia. However, the low alert and alarms minimize potential of harm. Our data demonstrate that TBR reduced following DynamicGM education and indicate that this approach can be both safe and effective in optimizing time in range.

The limitation of this report includes the lack of control group, nonetheless the effectiveness of the education program has been demonstrated in CYPD with hypoglycemia issues in a real-world F2F and VIRTUAL setting and merits a replication study with a control group. Despite intensive structured education teaching DynamicGM strategies, only 20% and 18% of F2F and VIRTUAL groups achieved ≥70%TIR. However, in our experience improving TIR by ~10% whilst significantly improving hypoglycemia in socioeconomically deprived cohort is clinically important. Engaging young children in the VIRTUAL program was more challenging compared to the F2F program. The GAME-SET-MATCH strategies used to improve TIR are associative and not yet proven to be causal.

6 | CONCLUSION

We present a real-world structured education program which effectively teaches DynamicGM, to improve glycemic control, even when delivered in a cost-saving VIRTUAL setting. Prioritizing the integration of the most effective DynamicGM strategies such as short bursts of exercise between meals, use of trend arrow adjustment tools, adjusting bolus timing and tailored hypoglycemia treatments can prevent overwhelming the user. Further simplification of these complex strategies into visual aids such as the GAME (Stop highs), SET (Stay in target) and MATCH (Prevent lows) mnemonic has been welcomed by the users.

AUTHOR CONTRIBUTIONS

John S. Pemberton: Concept, design, data gathering, researched data, manuscript writing and final approval. **Suma Uday:** Concept, design, researched data, statistical analysis; manuscript preparation, intellectual revision and final approval. **Timothy G, Barrett, Renuka P, Dias, Melanie Kershaw, Ruth Krone:** Intellectual revision and final approval.

ACKNOWLEDGMENTS

We would like to gratefully acknowledge the contribution of; the CGM Co-ordinator, Danielle Alcock, the diabetes dietitians Hilary McCoubrey and Catarina Leal and nurses Susan Gleeson, the CGM Committee members; Lesley Drummond, Louise Collins and Peter Eyre. We would like to thank the following clinicians involved in care delivery; Dr J Idkowiak, Dr Z Mohammed and Dr V Saraff. Children were followed up in the NIHR Wellcome Clinical Research Facility.

CONFLICT OF INTEREST

John S. Pemberton attended a SIGMA CGM educational event sponsored by Dexcom in 2019. All other authors have no conflicts of interest to declare. The work was undertaken as part of our service development, delivery and evaluation. The project was approved as service development by our institution's audit committee. Full permission is granted to reproduce all material in this work.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/pedi.13381.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Pemberton JS, Barrett TG, Dias RP, Kershaw M, Krone R, Uday S. An effective and cost-saving structured education program teaching dynamic glucose management strategies to a socio-economically deprived cohort with type 1 diabetes in a VIRTUAL setting. *Pediatr Diabetes*. 2022;1-12. doi:10.1111/pedi.13381