Diabetes, Obesity and Metabolism

WILEY

ORIGINAL ARTICLE OPEN ACCESS

Socioeconomic and Linguistic Factors in Paediatric Type 1 Diabetes: Exploring Glycemic Outcomes, Technology Use, and Residual Beta-Cell Function in Migrant-Background Populations

Silvia Savastio[1] | Andrea E. Scaramuzza[2] | Erica Pozzi[1] | Valeria Castorani[1] | Eleonora Chiarle[1] | Aurora Craici[1] | Valentina Todescato[2] | Claudio Cavalli[2] | Ivana Rabbone[1]

[1]Division of Pediatrics, Department of Health Sciences, University of Piemonte Orientale, Novara, Italy | [2]Pediatric Diabetes, Endocrinology and Nutrition, Pediatric Unit, ASST Cremona, Ospedale Maggiore, Cremona, Italy

Correspondence: Andrea E. Scaramuzza (a.scaramuzza@gmail.com)

Received: 14 June 2026 | **Revised:** 17 July 2026 | **Accepted:** 21 July 2026

Handling Editor: Johan Jendle

Keywords: adolescents | automated insulin delivery systems | children | coefficient of variation | glycated haemoglobin | migrant health | C-peptide | socioeconomic factors | time in range

ABSTRACT

Aims: To investigate associations between migrant status, socioeconomic factors (SES), and residual beta-cell function and glycemic outcomes in paediatric type 1 diabetes.

Methods: Retrospective study of 208 children (median [IQR] age 11 [8–14] years; 119 Italian, 89 from migrant-background families) with glucometric (HbA1c, TIR, TITR, TAR, CV), SES (maternal/paternal education, language, income), and metabolic data. Univariable and exploratory multivariable regression analyses identified factors associated with glycemic control.

Results: Children from migrant-background families presented with more severe metabolic crisis at onset (pH 7.28 vs. 7.35, $p = 0.047$; C-peptide 0.24 vs. 0.32 ng/mL, $p = 0.010$). Despite higher AID usage (80.6% vs. 68.1%), children from migrant-background families showed significantly worse glycemic control: higher HbA1c (7.8% vs. 7.0%, $p < 0.001$), lower TIR (57% vs. 65%, $p = 0.004$), and greater glycemic variability (CV 39.3% vs. 35.0%, $p < 0.001$). Socioeconomic disparities were marked, with 63.4% of migrant mothers unemployed (vs 16.6%, $p < 0.001$). In multivariable analysis, migrant status was associated with higher HbA1c (β +0.70, $p < 0.001$), while AID use (β +10, $p < 0.001$) and high maternal education (β +7.86, $p = 0.004$) were associated with higher TIR.

Conclusions: In this retrospective cohort, children and adolescents from migrant-background families had poorer glycemic outcomes despite high AID uptake and comparable C-peptide levels at follow-up. Technology provision alone may be insufficient to eliminate socioeconomic and linguistic disparities in glycemic control, and interventions targeting education, language support, and family-level self-management capacity may be beneficial.

1 | Introduction

Technology, especially automated insulin delivery (AID) systems [1], has delivered significant advances in the management of type 1 diabetes, particularly for children and adolescents. AID systems are now helping more young people attain ISPAD targets of HbA1c < 7% and a time in range (TIR; between 70 and 180 mg/dL) of > 70%, indicators of good

Silvia Savastio and Andrea E. Scaramuzza contributed equally to this paper.

metabolic control [2], noting that a time in tight range (TITR) of > 55% is desirable to reduce the risk of complications and increase life expectancy [3].

Nevertheless, achieving optimal metabolic control remains challenging, often due to the complexities of technology use or other factors. There is evidence showing that migrant status can significantly influence type 1 diabetes management, potentially affecting metabolic and long-term outcomes [4–7]. This is frequently attributed to a combination of genetic, cultural, and socioeconomic barriers that hinder effective disease management.

As of early 2026, 5.4 million foreign individuals were estimated to reside in Italy, accounting for 9.2% of the total population [8]. Studies from the US indicate a higher incidence of type 1 diabetes among ethnic minorities [9], and data from Italy corroborate these findings; the Italian DAWN study, for instance, revealed that the incidence of type 1 diabetes in the migrant-background population was twofold higher than in the native Italian population [10]. Furthermore, individuals who migrate from low- to high-risk regions for type 1 diabetes tend to adopt the disease risk level of their destination country, probably due to exposure to new environmental triggers, which may contribute to type 1 diabetes onset in genetically predisposed individuals [5, 11, 12]. Other factors such as legal status, socioeconomic conditions, access to healthcare, and post-migration lifestyle changes can negatively impact health-related quality of life and impede optimal glycemic control [5, 13, 14].

While technology like insulin pumps and continuous glucose monitoring (CGM) and residual beta-cell function are known to be associated with improved outcomes [15], it remains unclear if different socioeconomic strata benefit equally from these biological and technical advantages. Given the existing data on socioeconomic disparities, we hypothesised that children from migrant-background families would have poorer glycemic outcomes despite comparable access to diabetes technology.

2 | Methods

2.1 | Study Design and Participants

Consecutive patients attending Novara Hospital and ASST Cremona Hospital between January 1, 2023 and December 31, 2025 were included. Inclusion criteria were a diagnosis of type 1 diabetes and age between 0 and 18 years. Exclusion criteria were a diagnosis of anorexia nervosa or other eating disorders, concurrent genetic diseases, ongoing chronic treatments that could affect glycemic control (e.g., corticosteroids, immunosuppressive drugs), or having a last clinic visit prior to January 2023.

The study was conducted in accordance with the Declaration of Helsinki. This was a non-interventional, retrospective study using fully anonymized and aggregated data extracted from hospital data management platforms. In compliance with the Italian General Authorization to Process Personal Data for Scientific Research Purposes (authorization 9/2014), which covers studies based on such anonymized real-world data, formal ethics committee approval and separate informed consent were not required beyond the initial consent provided by users.

2.2 | Data Collection and Clinical Assessment

Auxological and anamnestic data were collected, including the birthplace of both the patients and their parents, along with comorbidities such as celiac disease and thyroiditis. Metabolic parameters were evaluated at the most recent clinic visit.

2.3 | Treatment and Technology

For analytical purposes, therapies were categorised as multiple daily injections (MDI) or AID (MiniMed 780G, myLife loop, Omnipod 5, Tandem t:slim Control-IQ). Data from CGM devices were extracted using platform-specific software, including Carelink, Glooko, Libreview, Diasend, Dexcom Clarity, and Glucolog. Notably, 25 patients used insulin pumps without automated algorithms (open-loop pumps, typically older-generation devices). These patients were analysed separately and are included in comparative descriptive analyses but were categorised as "non-AID" for regression purposes, given the lack of algorithmic automation. This categorization was selected to isolate the algorithmic automation effect in line with our primary hypothesis.

2.4 | Outcomes and Variables

The primary outcome was HbA1c, while secondary outcomes included key sensor metrics and biochemical parameters. Glycemic metrics included TIR (70–180 mg/dL), time above range (TAR, > 180 mg/dL), time below range (TBR, < 70 mg/dL), TITR (70–140 mg/dL), and the coefficient of variation (CV) as a marker of glucose variability. Biochemical data included C-peptide levels, insulin requirements (IU/kg/day), total cholesterol, LDL and HDL cholesterol, triglycerides, vitamin D, microalbuminuria, and TSH. HbA1c was assessed as both the most recent value and the annual mean of four measurements.

For each patient, data were collected at two time-points: diagnosis (onset) and the current clinical visit (T1). At onset, we recorded age at diagnosis, body mass index (BMI), presence of diabetic ketoacidosis (DKA), and residual beta-cell function via fasting C-peptide levels (ng/mL). At T1, we recorded chronological age, disease duration, and BMI. Anthropometric measurements (weight and height) were standardized using World Health Organization (WHO) z-scores. Blood pressure was measured using a validated oscillometric device, and systolic (SBP) and diastolic (DBP) values were recorded.

HbA1c was measured using high-performance liquid chromatography (HPLC), standardized to the DCCT reference. CGM

and flash glucose monitoring (FGM) data were extracted strictly from the previous 14 days of sensor use, requiring an active sensor wear time threshold of ≥ 70%. At T1, a fasting blood draw was performed to evaluate total cholesterol, HDL, LDL, triglycerides, TSH, free T4, C-peptide levels and vitamin D. Renal health was screened via microalbuminuria (mg/L) in a spot morning urine sample.

2.5 | Socioeconomic Variables

To assess the impact of the 'user environment', we collected robust proxy indicators for socioeconomic status (SES): (a) maternal and paternal education, categorised as low (primary/middle), medium (high school), and high (degree/post-grad), where for the regression models and binary text comparisons, 'high maternal education' was defined as the completion of secondary high school or higher (medium + high tracks) versus lower secondary school or less; (b) maternal and paternal occupation, categorised as unemployed, manual/non-skilled, and office/professional; (c) family income, categorised by annual household income brackets (< 26 000 €, 26 000–55 000 €, > 55 000 €); and (d) linguistic proficiency, assessed for both parents on a scale evaluating ability to execute medical instructions (good vs basic/intermediate). There was no systematic stratification by religious observance, but glycemic data for families observing Ramadan fasting were collected exclusively during non-fasting periods to avoid confounding.

2.6 | Statistical Analysis

Statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk test showed a non-normal data distribution for all variables, so continuous variables were expressed as median and interquartile range (IQR). Differences between the Italian group and migrant-background group were assessed using the Mann–Whitney *U* test. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

For multivariable analysis, a linear regression approach was used to explore factors associated with HbA1c and TIR. While a priori variable selection based on causal reasoning may be preferable to univariable screening, our exploratory models employed a hybrid approach combining literature-based reasoning and univariable association testing to select parsimonious predictors. Variables selected a priori were migrant status, AID use, maternal education, and C-peptide levels. Maternal education displayed high collinearity with paternal education ($r = 0.72$, Pearson correlation), so in families with two parents present, maternal education was selected for inclusion as it often serves as a stronger proxy for health literacy regarding pediatric self-management, as mothers typically attend more frequent clinic visits and are more directly involved in daily diabetes management. To preserve statistical power, the HbA1c model was not adjusted for age. Model diagnostics included the calculation of R^2, adjusted R^2, and variance inflation factors (VIF) to rule out multicollinearity. A *p*-value of < 0.05 was considered statistically significant.

3 | Results

3.1 | Clinical and Socioeconomic Characteristics

A total of 208 children and adolescents with type 1 diabetes were evaluated (median [IQR] age: 11.0 [8.0–14.0] years; 123 males, 85 females). The cohort comprised 119 participants of native Italian origin (ITA group) and 89 participants from a migrant background (MIG group). A participant was classified under the migrant-background cohort if at least one parent was of non-Italian origin. 179 patients (86%) used insulin pump therapy and 29 (14%) used MDI. Among the pump users, 154 (86%) individuals were treated with an AID system.

Of the 89 children from migrant-background families, 55 (62%) originated from Africa (Egypt, Morocco, Tunisia, Algeria, Senegal), 21 (24%) from Eastern Europe (Albania, Romania, Ukraine), 10 (11%) from Asia (Syria, Iran, Iraq, Turkey, Pakistan, India, China, Sri Lanka), and 3 (3%) from Central and South America (Brazil and the Caribbean). Most of these families originated from low-, lower-middle-income, or transitional economies, supporting the interpretation that observed disparities are primarily driven by socioeconomic disadvantage rather than the selection of high-education immigrant professionals. The majority of migrant-background children were born in Italy (70/89, 79%) and experienced type 1 diabetes onset in Italy (85/89, 95%). The migrant-background cohort was significantly younger at both disease onset (median 5.0 vs. 7.0 years, $p = 0.019$) and at the study visit (9.5 vs. 12.0 years, $p = 0.002$) (Table 1).

Marked socioeconomic differences were observed between Italian and migrant-background families (Table 2). Migrant-background families had lower rates of high maternal (52.4% vs. 70.4%, $p = 0.012$) and paternal (45.9% vs. 66.9%, $p = 0.004$) education, as evaluated as completion of secondary high school or higher. Migrant-background mothers were significantly more likely to be unemployed (63.4% vs. 16.6%, $p < 0.001$) and possess lower educational attainment (only 9.5% with a degree vs. 34.3% Italian, $p < 0.001$). Crucially, linguistic proficiency was a major barrier: only 12.5% of migrant-background mothers had "good" Italian proficiency compared to near-universal fluency in the Italian group ($p < 0.001$). Family income distribution also skewed lower for migrants, but not as much as for education/occupation.

3.2 | Biological Markers and Glycemic Outcomes

At onset, children from migrant-background families presented with more severe metabolic crisis (pH median 7.28 vs. 7.35, $p = 0.047$) and significantly lower C-peptide levels (0.24 vs. 0.32 ng/mL, $p = 0.010$). However, at the study visit (T1), there were no statistically significant differences in residual C-peptide levels between groups (Table 1). Despite this and a higher rate of AID system use in children from migrant-background families (80.6% vs. 68.1%), this cohort had significantly worse glycemic control (Table 3), with higher HbA1c (7.8% vs. 7.0%, $p < 0.001$), lower TIR (57% vs. 65%, $p = 0.004$), and significantly higher CV (39.3% vs. 35.0%, $p < 0.001$).

At follow-up, children from migrant-background families also had significantly lower vitamin D levels (20.1 vs. 24.2 ng/mL, $p = 0.017$) (Table 1) and used significantly less basal insulin per

TABLE 1 | Clinical, anthropometric, and laboratory characteristics.

	Italian group ($n=119$)	Migrant-background group ($n=89$)	p
Age at T1 (years)	12.00 (9.00–15.00)	9.50 (7.00–13.00)	**0.002**
Diabetes duration at T1 (years)	5.00 (2.00–7.00)	4.00 (1.00–7.00)	0.078
Age at onset (yrs)	7.00 (4.00–9.00)	5.00 (2.00–8.00)	**0.019**
BMI z-score (T1)	0.46 (−0.22–1.09)	0.98 (0.35–1.60)	**0.012**
BMI z-score (onset)	−0.60 (−1.32–0.40)	−0.11 (−1.30–0.62)	0.482
Systolic BP at T1 (mmHg)	110 (102–118)	108 (100–115)	0.215
Diastolic BP at T1 (mmHg)	62.00 (58.00–68.00)	60.00 (54.00–66.50)	0.227
pH at diabetes onset	7.35 (7.23–7.39)	7.28 (7.10–7.35)	**0.047**
HCO_3 at diabetes onset	18.60 (10.70–22.35)	15.95 (5.95–21.08)	0.149
C-peptide at diabetes onset (ng/mL)	0.32 (0.20–0.55)	0.24 (0.14–0.40)	**0.010**
C-peptide at T1 (ng/mL)	0.01 (0.01–0.14)	0.03 (0.01–0.28)	0.118
Vitamin D at T1 (ng/mL)	24.20 (19.70–30.30)	20.10 (13.50–27.30)	**0.017**
Total cholesterol at T1 (mg/dL)	165 (148–188)	162 (140–181)	0.145
LDL cholesterol at T1 (mg/dL)	81 (69–101)	85 (74–104)	0.611
HDL cholesterol at T1 (mg/dL)	55 (48–64)	52 (45–60)	0.210
Triglycerides at T1 (mg/dL)	56 (44–71)	56 (42–88)	0.238
Microalbuminuria at T1 (mg/L)	4.90 (2.45–10.45)	4.80 (2.90–9.70)	0.856

Note: The values in bold mean they are significantly different between groups.

kilogram (median 0.33 vs. 0.38 U/kg, $p=0.010$), while the total daily dose was similar (Table 3).

3.3 | Multivariable Predictors

Exploratory regression analysis (Table 4) indicated that migrant-background status was independently associated with higher HbA1c (β +0.70, $p<0.001$; VIF 1.28). For TIR, AID system use (β +10.10, $p<0.001$; VIF 1.15) and high maternal education (β +7.86, $p=0.004$; VIF 1.34) were independently associated with higher TIR, while migrant status was associated with lower TIR (β −7.85, $p=0.008$; VIF 1.41). In the models tested, neither occupation nor income reached statistical significance as independent predictors of glycemic outcomes when education was included. Overall model fit was robust, with no indication of significant multicollinearity.

4 | Discussion

Socioeconomic and linguistic determinants influence glycemic control in type 1 diabetes through a complex interplay that shapes treatment response and long-term clinical outcomes [16, 17]. Here we observed a significant disparity in paediatric diabetes management that challenges a widespread assumption in modern diabetes care, namely that despite equal (in this cohort, superior) access to AID technology, children from migrant-background families experience significantly poorer metabolic outcomes and higher glycemic variability than their native peers.

While glycemic control was suboptimal in our population relative to international standards (HbA1c 7.3% ± 0.9%; TIR < 70%), our results are consistent with European registry data and compare favourably to the American T1D Exchange Registry [18, 19]. Nevertheless, Italian children achieved markedly superior control across all metrics, with lower HbA1c ($p<0.0001$), higher TIR ($p=0.004$), and higher TITR (70–140 mg/dL; $p=0.001$). These findings corroborate existing literature highlighting the metabolic vulnerability of migrant paediatric populations from migrant backgrounds [4, 5, 7, 12, 20, 21].

Our findings suggest that similar C-peptide concentrations did not translate into similar glycemic outcomes, indicating that factors beyond residual beta-cell function contribute to these variations. Residual beta-cell function typically serves as a biological buffer against glycemic instability [15, 22]. Although we hypothesized that children with similar C-peptide reserves would derive comparable metabolic benefits, despite having similar C-peptide levels at the study visit, children from migrant-background families did not achieve the expected glycemic stability or reduced CV observed in their Italian peers. At follow-up (T1), the median C-peptide values were extremely low in both groups (0.01 vs. 0.03 ng/mL), representing an advanced stage of beta-cell depletion where minimal remaining endogenous secretion lacks the absolute capacity to buffer against day-to-day self-management challenges.

Counterintuitively, AID system use was significantly higher in the migrant-background group (80.6%) than the Italian group (68.1%, $p=0.042$), which probably reflects a proactive clinical prescribing strategy rather than patient demand. In Italy, the

TABLE 2 | Socioeconomic and linguistic profile.

	Italian group ($n = 119$)	Migrant-background group ($n = 89$)	p
Maternal education			
High (University Degree)	34.3%	9.5%	**0.0004**
Medium (High School 4-5y)	36.1%	42.9%	
Low (Middle School or less)	29.7%	47.6%	
Paternal education			
High (University Degree)	31.2%	2.7%	**0.0041**
Medium (High School 4–5 years)	35.8%	43.2%	
Low (Middle School or less)	33.0%	54.1%	
Maternal occupation			
Unemployed	16.6%	63.4%	**< 0.0001**
Skilled/ Professional	45.4%	13.5%	
Manual/ Non-skilled	38.0%	23.1%	
Italian language (mother)			
Good Proficiency	99.2%	50.0%	**< 0.0001**
Basic/ Intermediate	0.8%	50.0%	
Italian language (father)			
Good Proficiency	100.0%	59.7%	**< 0.0001**
Intermediate/ Basic	0.0%	40.3%	
Family income			
< 26 000 €/ year	30.6%	51.7%	0.1881
26 000–54 999 €/year	66.1%	44.8%	
> 55 000 €/ year	3.2%	3.4%	

Note: The values in bold mean they are significantly different between groups.

TABLE 3 | Glucometrics and insulin doses (last 14 days).

	Italian group ($n = 119$)	Migrant-background group ($n = 89$)	p
HbA1c (%)	7.00 (6.45–7.60)	7.80 (7.00–8.40)	**< 0.001**
HbA1c (mmol/ mol)	53 (47–60)	62 (53–68)	**< 0.001**
TIR 70–180 mg/ dL (%)	65.00 (56.00–76.00)	57.00 (46.25–69.75)	**0.004**
TITR 70–140 mg/dL (%)	39.5 (31.0–48.0)	31.2 (23.5–41.0)	**0.001**
TAR > 180 mg/ dL (%)	23.00 (18.00–27.00)	22.00 (19.00–26.00)	0.943
TAR > 250 mg/ dL (%)	8.00 (3.00–16.00)	15.50 (7.00–24.75)	**< 0.001**
TBR < 70 mg/ dL (%)	2.00 (1.00–3.00)	2.00 (1.00–3.00)	0.342
TBR < 54 mg/ dL (%)	0.00 (0.00–0.00)	0.00 (0.00–1.00)	0.056
CV (%)	35.00 (31.55–39.90)	39.30 (34.50–42.70)	**< 0.001**
Mean glucose (mg/dL)	161.0 (144.0–178.0)	171.0 (152.5–200.5)	**0.032**
GMI (%)	7.0 (6.6–7.4)	7.5 (6.9–8.1)	**0.002**
Total daily dose (U/kg)	0.82 (0.65–0.98)	0.80 (0.60–1.02)	0.540
Basal insulin (U/kg)	0.38 (0.30–0.46)	0.33 (0.27–0.41)	**0.010**
Bolus insulin (U/kg)	0.44 (0.32–0.55)	0.47 (0.35–0.62)	0.280
Basal % of total dose	46.3 (41.0–52.0)	41.2 (36.0–48.5)	**0.005**

Note: Among pump users ($n = 179$), 154 used AID systems and 25 used non-automated (open-loop) pumps. For regression analyses, non-automated pumps were classified as "non-AID" to isolate the algorithmic automation effect. The values in bold mean they are significantly different between groups.

National Health Service (SSN) provides full financial reimbursement for advanced diabetes technologies (insulin pumps and CGM systems), eliminating direct financial barriers. Clinical protocols at both study centers prioritize prescribing AID systems to socioeconomically vulnerable or geographically complex families to provide an automated safety net against severe dysglycemia (DKA, severe hypoglycemia). Migrant-background families, who may experience more linguistic and educational barriers to intensive self-management, may therefore have been preferentially offered AID systems by providers as a harm-reduction strategy. This prescribing approach explains the higher adoption rate but also highlights that technology provision alone does not eliminate disparities, as despite 80.6% AID use, children from migrant-background families still had significantly higher HbA1c and lower TIR. This reveals a fundamental gap between device adoption and therapeutic optimization. The disparity was most notable for TITR, a metric reflecting algorithmic precision and suggesting that while the advanced

TABLE 4 | Multivariate linear regression models with advanced diagnostics.

Predictor	β	SE	95% CI	p	VIF
HbA1c model ($n = 200$, Adj. $R^2 = 0.487$, $F = 24.61$, $p < 0.001$)					
Migrant status	+0.70	0.17	[0.37, 1.03]	<0.001*	1.18
AID system use	−0.48	0.16	[−0.79, −0.17]	0.005	1.09
High maternal education	−0.16	0.16	[−0.47, 0.15]	0.311	1.23
C-peptide at T1	−0.16	0.12	[−0.39, 0.07]	0.193	1.05
Predictor	**β**	**SE**	**95% CI**	**p**	**VIF**
TIR model ($n = 205$, Adj. $R^2 = 0.392$, $F = 33.08$, $p < 0.001$)					
AID system use	+10.10	2.77	[4.63, 15.57]	<0.001*	1.09
High maternal education	+7.86	2.71	[2.51, 13.21]	0.004	1.23
Migrant status	−7.85	2.90	[−13.58, −2.12]	0.008	1.18
Age at T1 (years)	−0.70	0.32	[−1.33, −0.07]	0.034*	1.08

*The values in bold mean they are significantly different between groups.

technology was active, optimal user-algorithm interaction was compromised by socioeconomic and educational barriers.

The migrant-background group had significantly lower basal insulin requirements (0.32 IU/kg/day vs. 0.42 IU/kg/day, $p = 0.001$). This difference is probably due to the younger median age of the migrant-background cohort at follow-up, as basal insulin requirements increase progressively during pubertal development and adolescence. While detailed data on manual bolus frequency, automatic correction bolus delivery, and carbohydrate-entry patterns were not available, the higher TAR (> 180 mg/dL) in the migrant-background group may suggest suboptimal meal bolus timing, inadequate carbohydrate estimation, or delayed response to hyperglycemic alerts.

While this study did not assess quantitative dietary intake, carbohydrate estimation precision, or physical activity patterns, these factors represent potentially important contributors to glycemic outcomes independent of technology access. Recent evidence demonstrates that dietary inflammatory potential is independently associated with HbA1c and cardiometabolic risk in paediatric type 1 diabetes [23]. Families with lower health literacy or language barriers may face additional challenges to precise carbohydrate counting and selection of meals with favourable glycemic impact. Beyond technology provision, diabetes education addressing nutritional quality, carbohydrate estimation strategies, and family-level self-management behaviours may be essential to achieve optimal glycemic outcomes in migrant-background populations.

Exploratory multivariate regression analysis indicated that migrant-background status remained an independent factor associated with increased HbA1c regardless of AID use. This persistence despite widespread technology adoption suggests a major gap between device deployment and device use. Despite device provision, the linguistic and educational barriers required to optimise automated management (e.g., precise carbohydrate counting, interpretation of trend arrows, response to complex alarm algorithms) still appear to be an issue. The finding that maternal education was independently associated with higher TIR, independent of family income or parental occupation, further emphasises the importance of this educational dimension. The sophisticated features of modern AID systems may be substantially underutilized in families with lower health literacy and significant language barriers, as evidenced by the significantly higher TAR > 250 mg/dL in the migrant-background group. The ability to manage complex AID algorithms, interpret glucose trend patterns, perform precise carbohydrate estimation, and respond rapidly to alarms depends heavily on health literacy and language proficiency, domains that were lowest in migrant-background mothers (only 9.5% with university education; 50% with limited language proficiency), similar to Gesuita et al. [14], who also found that maternal education remains a dominant independent predictor of metabolic success [24]. Closing this socio-biological gap relies on moving clinical interventions beyond standard educational models. Families from ethnic and migrant minorities can achieve metabolic parity with native peers when provided with appropriately tailored, culturally responsive support [25].

At disease onset, children from migrant-background families presented with more severe DKA and significantly lower initial C-peptide, suggesting either delayed access to care in the pre-diagnosis period or a more aggressive initial autoimmune response in this population. Either mechanism places these children at greater metabolic risk over the disease trajectory. Furthermore, children from migrant-background families exhibited significantly higher BMI z-scores, which are closely associated with insulin resistance, poorer glycemic control, and increased long-term cardiovascular risk [26].

This study has several limitations. First, as a retrospective cohort study, our design precludes assertions of direct causality regarding technology use, socioeconomic factors, and glycemic outcomes. Second, the migrant-background cohort was significantly younger at follow-up, and the HbA1c multivariable model was not adjusted for age to preserve statistical power within the sample constraints. This is an important limitation, as pubertal status and its associated physiological insulin resistance are major drivers of glycemic control during adolescence. Third, as linguistic proficiency was assessed through clinical judgment during routine interactions rather than validated, standardized linguistic testing, there is potential for subjectivity and bias. Fourth, while primary categorization isolated the algorithmic effect (AID vs. non-AID), we lacked granular data regarding specific device models, total duration of device use prior to T1, software update versions, sensor wear-time consistency beyond the ≥ 70% threshold, and specific automated parameters (such

as auto-bolus frequency or carbohydrate-entry errors), which may have also introduced bias. Fifth, data were collected across two high-volume paediatric diabetes centers in Northern Italy, and although clinical protocols are standardized, unmeasured center-specific prescribing habits, local cultural dynamics, and regional socioeconomic characteristics may limit generalizability to other regions or different international healthcare systems. Finally, there is known genetic variability in red blood cell lifespan and glycation rates (particularly in patients of African origin, who comprised 62% of our migrant cohort) that may affect HbA1c values, potentially confounding comparisons with native populations. Furthermore, data collection overlapped with annual religious observances like Ramadan, and although we mitigated this by strictly upgrading and extracting glycemic metrics during non-fasting periods, residual behavioural or metabolic confounding from religious fasting patterns cannot be completely excluded.

5 | Conclusions

In this retrospective cohort, children and adolescents from migrant-background families had poorer glycemic outcomes despite high AID uptake and comparable C-peptide levels at follow-up. Our findings suggest that technology provision alone may be insufficient to eliminate socioeconomic and linguistic disparities in glycemic control, and that interventions targeting education, language support, and family-level self-management capacity may be beneficial.

Author Contributions

S.S., I.R., and A.E.S. conceived the study, collected data, supervised data collection, and critically discussed the results. S.S. and A.E.S. ran the statistical analysis. S.S. and A.E.S. drafted the report. E.P., E.C., A.C., and V.T. collected data, critically discussed the findings, revised the first draft, and approved the final draft of the manuscript. A.E.S. wrote the final version of the report. I.R. and C.C. supervised the study and critically assessed the data and the final version of the paper.

Acknowledgements

The corresponding author (AES) had full access to the data, and the corresponding author made the final decision to submit for publication. We would like to thank our patients with type 1 diabetes and their families who participated in the study. Open access publishing facilitated by Azienda Socio Sanitaria Territoriale di Cremona, as part of the Wiley - SBBL agreement.

Funding

The authors have nothing to report.

Conflicts of Interest

Andrea E. Scaramuzza is on the advisory board of Abbott, Medtronic, Movi, Sanofi, Theras and University Bocconi; has received travel grants from Ypsomed and Abbott. Ivana Rabbone has received grants to the author or organization from Sanofi and Medtronic, and personal fees (e.g., honoraria, consulting fees, lecture fees) from Sanofi, Theras, Menarini, and Movi. Silvia Savastio, Eleonora Chiarle, Aurora Craici, Valentina Todescato and Claudio Cavalli have no conflicts of interest to declare. All authors declare they have no conflict-of-interest to disclose related to the present study, its data collection, analysis and presentation.

Data Availability Statement

Data are available from the corresponding author upon reasonable written request.

Peer Review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/dom.71167.

References

1. H. S. de Visser, S. Waraich, M. Chhabra, et al., "Automated Insulin Delivery Systems and Glucose Management in Children and Adolescents With Type 1 Diabetes: A Systematic Review and Meta-Analysis," *JAMA Pediatrics* 179, no. 11 (2025): 1162–1171, https://doi.org/10.1001/jamapediatrics.2025.2740.

2. M. de Bock, J. C. Agwu, M. Deabreu, et al., "International Society for Pediatric and Adolescent Diabetes Clinical Practice Consensus Guidelines 2024: Glycemic Targets," *Hormone Research in Pædiatrics* 97, no. 6 (2024): 546–554, https://doi.org/10.1159/000543266.

3. P. Bahillo-Curieses, P. Fernandez Velasco, P. Perez-Lopez, A. M. Vidueira Martinez, M. O. Nieto de la Marca, and G. Diaz-Soto, "Utility of Time in Tight Range (TITR) in Evaluating Metabolic Control in Pediatric and Adult Patients With Type 1 Diabetes in Treatment With Advanced Hybrid Closed-Loop Systems," *Endocrine* 86, no. 2 (2024): 539–545, https://doi.org/10.1007/s12020-024-03881-6.

4. A. R. Kahkoska, C. M. Shay, J. Crandell, et al., "Association of Race and Ethnicity With Glycemic Control and Hemoglobin A(1c) Levels in Youth With Type 1 Diabetes," *JAMA Network Open* 1, no. 5 (2018): e181851, https://doi.org/10.1001/jamanetworkopen.2018.1851.

5. B. Predieri, P. Bruzzi, E. Bigi, et al., "Health-Related Quality of Life and Metabolic Control in Immigrant and Italian Children and Adolescents With Type 1 Diabetes and in Their Parents," *Pediatric Diabetes* 21, no. 6 (2020): 1031–1042, https://doi.org/10.1111/pedi.13042.

6. N. Scheuing, S. Wiegand, C. Bachle, et al., "Impact of Maternal Country of Birth on Type-1-Diabetes Therapy and Outcome in 27,643 Children and Adolescents From the DPV Registry," *PLoS One* 10, no. 8 (2015): e0135178, https://doi.org/10.1371/journal.pone.0135178.

7. U. Soderstrom, U. Samuelsson, and J. Aman, "National Swedish Study of Immigrant Children With Type 1 Diabetes Showed Impaired Metabolic Control After Three Years of Treatment," *Acta Paediatrica* 105, no. 8 (2016): 935–939, https://doi.org/10.1111/apa.13456.

8. Italy, "New Report Snapshots Data on Citizenship, Wellbeing and Education," 2025, https://www.infomigrants.net/en/post/68854/italy-new-report-snapshots-data-on-citizenship-wellbeing-and-education.

9. J. Divers, E. J. Mayer-Davis, J. M. Lawrence, et al., "Trends in Incidence of Type 1 and Type 2 Diabetes Among Youths - Selected Counties and Indian Reservations, United States, 2002-2015," *Morbidity and Mortality Weekly Report* 69, no. 6 (2020): 161–165, https://doi.org/10.15585/mmwr.mm6906a3.

10. M. Abis, M. Massi Benedetti, M. A. Comaschi, and P. Pisanti, "Organizzazione e Gestione dell'assistenza Diabetologica. Lo studio DAWN (Diabetes Attitudes, Wishes and Needs)," *Il Diabete* 19, no. 4 (2007): 254–266.

11. H. I. Hussen, T. Moradi, and M. Persson, "The Risk of Type 1 Diabetes Among Offspring of Immigrant Mothers in Relation to the Duration of Residency in Sweden," *Diabetes Care* 38, no. 5 (2015): 934–936, https://doi.org/10.2337/dc14-2348.

12. U. Soderstrom, J. Aman, and A. Hjern, "Being Born in Sweden Increases the Risk for Type 1 Diabetes - a Study of Migration of Children to Sweden as a Natural Experiment," *Acta Paediatrica* 101, no. 1 (2012): 73–77, https://doi.org/10.1111/j.1651-2227.2011.02410.x.

13. P. J. Carter, W. S. Cutfield, P. L. Hofman, et al., "Ethnicity and Social Deprivation Independently Influence Metabolic Control in Children With Type 1 Diabetes," *Diabetologia* 51, no. 10 (2008): 1835–1842, https://doi.org/10.1007/s00125-008-1106-9.

14. R. Gesuita, E. Skrami, R. Bonfanti, et al., "The Role of Socio-Economic and Clinical Factors on HbA1c in Children and Adolescents With Type 1 Diabetes: An Italian Multicentre Survey," *Pediatric Diabetes* 18, no. 3 (2017): 241–248, https://doi.org/10.1111/pedi.12378.

15. A. Lam, C. Dayan, and K. C. Herold, "A Little Help From Residual Beta Cells Has Long-Lasting Clinical Benefits," *Journal of Clinical Investigation* 131, no. 3 (2021): e143683, https://doi.org/10.1172/JCI143683.

16. M. Fritsch, J. Rosenbauer, E. Schober, et al., "Predictors of Diabetic Ketoacidosis in Children and Adolescents With Type 1 Diabetes. Experience From a Large Multicentre Database," *Pediatric Diabetes* 12, no. 4 (2011): 307–312, https://doi.org/10.1111/j.1399-5448.2010.00728.x.

17. W. H. Herman and R. M. Cohen, "Racial and Ethnic Differences in the Relationship Between HbA1c and Blood Glucose: Implications for the Diagnosis of Diabetes," *Journal of Clinical Endocrinology and Metabolism* 97, no. 4 (2012): 1067–1072, https://doi.org/10.1210/jc.2011-1894.

18. J. M. Hermann, K. M. Miller, S. E. Hofer, et al., "The Transatlantic HbA(1c) Gap: Differences in Glycaemic Control Across the Lifespan Between People Included in the US T1D Exchange Registry and Those Included in the German/Austrian DPV Registry," *Diabetic Medicine* 37, no. 5 (2020): 848–855, https://doi.org/10.1111/dme.14148.

19. R. A. Lal, H. Robinson, S. Lanzinger, et al., "Temporal Changes in Hemoglobin A1c and Diabetes Technology Use in DPV, NPDA, and T1DX Pediatric Cohorts From 2010 to 2018," *Diabetes Technology & Therapeutics* 24, no. 9 (2022): 628–634, https://doi.org/10.1089/dia.2022.0095.

20. P. Banin, F. Rimondi, A. De Togni, et al., "Type 1 Diabetes (T1DM) in Children and Adolescents of Immigrated Families in Emilia-Romagna (Italy)," *Acta Bio-Medica* 81, no. 1 (2010): 35–39.

21. F. Cadario, F. Cerutti, S. Savastio, et al., "Increasing Burden, Younger Age at Onset and Worst Metabolic Control in Migrant Than in Italian Children With Type 1 Diabetes: An Emerging Problem in Pediatric Clinics," *Acta Diabetologica* 51, no. 2 (2014): 263–267, https://doi.org/10.1007/s00592-013-0514-6.

22. C. M. Fuhri Snethlage, T. J. McDonald, R. D. Oram, et al., "Residual Beta-Cell Function Is Associated With Longer Time in Range in Individuals With Type 1 Diabetes," *Diabetes Care* 47, no. 7 (2024): 1114–1121, https://doi.org/10.2337/dc23-0776.

23. İ. M. Alptekin, T. Ekinci Gezmiş, F. B. Özgeriş, Z. Şahin, N. Öztürk, and Z. Orbak, "Dietary Inflammatory Index and Cardiometabolic and Inflammatory Profiles in Children and Adolescents With Type 1 Diabetes: A Cross-Sectional Study," *Pediatric Research* (2026), https://doi.org/10.1038/s41390-026-05069-2.

24. R. Franceschi, M. Canale, E. M. Piras, et al., "Influence of Parental Health Locus of Control on Behavior, Self-Management and Metabolic Control, in Pediatric Patients With Type 1 Diabetes," *Journal of Personalized Medicine* 12, no. 10 (2022): 1590, https://doi.org/10.3390/jpm12101590.

25. B. Iovane, A. M. Cangelosi, I. Bonaccini, et al., "Effectiveness of a Tailored Medical Support to Overcome the Barriers to Education, Treatment and Good Metabolic Control in Children With Type-1 Diabetes From Ethnic Minorities," *Acta Bio Medica: Atenei Parmensis* 88, no. 4 (2018): 477–482, https://doi.org/10.23750/abm.v88i4.6779.

26. J. Edqvist, A. Rawshani, M. Adiels, et al., "BMI, Mortality, and Cardiovascular Outcomes in Type 1 Diabetes: Findings Against an Obesity Paradox," *Diabetes Care* 42, no. 7 (2019): 1297–1304, https://doi.org/10.2337/dc18-1446.