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Research Article

Inequalities in Access to Diabetes Technologies in Children with Type 1 Diabetes: A Multicenter, Cross-sectional Study from Türkiye

Karakus KE et al. Access to Diabetes Technologies

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What is already known on this topic?
Technology use improves type 1 diabetes management in children regardless of socioeconomic status. However, access to technology has socioeconomic barriers.

What this study adds?
We showed that socioeconomic characteristics affect access to diabetes technologies and glycemic management in a large group of families from Türkiye.

Abstract
Objective: To determine inequalities in access to diabetes technologies and the effect of socioeconomic factors on families with children with type 1 diabetes.
Methods: In this multicenter cross-sectional study, parents of children with type 1 diabetes completed a questionnaire about household sociodemographic characteristics, latest HbA1c values, continuous glucose monitoring (CGM) and insulin pump use of children, the education and working status of parents. These characteristics were compared between technology use (only-CGM, only-pump, CGM+pump, no technology use).
Results: Among 882 families, only-CGM users, only-pump users, and CGM+pump users compared with no technology users, adjusting for age, sex, region, education levels, number of working parents, and household income. Children living in the least developed region had lower odds of having only-CGM (OR=0.20, 95%CI 0.12–0.34) and having CGM+pump (OR=0.07, 95%CI 0.03–0.22) compared with those living in the most developed region. Children with parents who had not finished high school had lower odds of having only-CGM (Mothers: OR=0.36, 95%CI 0.19–0.66; fathers: OR=0.32, 95%CI 0.18–0.60) or both CGM+pump (OR=0.27, 95%CI 0.11–0.64; fathers: OR=0.34, 95%CI 0.15–0.79) rather than no-technology compared to children whose parents has a university degree. Every $840 increase in the household income increased the odds by 5% for having only-CGM (OR=1.05, 95%CI 1.02–1.09) and CGM+pump (OR=1.05, 95%CI 1.01–1.08).
Conclusion: Socioeconomic factors such as education, regions, and income were associated with inequality in access to technologies. The inequalities are more prominent in access to CGM while CGM had a bigger contribution to glycemic control.
Keywords: Continuous glucose monitoring, inequality, technology, type 1 diabetes

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Introduction

In the last decade, diabetes technologies, especially continuous glucose monitoring (CGM), have played an increasingly fundamental role in the treatment of children with type 1 diabetes (T1D). In parallel, ensuring equal access to these technologies and evaluating inequalities in a multidimensional manner has become a matter of debate (1-3). Inequalities are directly related to the historical and current unequal distribution of social, political, economic, and environmental resources, and one of the groups most affected by inequalities is children (4). Inequalities in access to diabetes technologies should be addressed within the scope of "social determinants of health", screened routinely by healthcare providers in visits, and should be made the subject of advocacy for the social rights of children (5-7).

Equal access to CGM from diagnosis can lower HbA1c in children despite other inequalities, and thus can be a "leverage" to reduce the impact of inequalities on children's diabetes (8). The relationship between families and CGM goes beyond the numbers, CGM eases families' burden and reinforces their motivation to be "their children's pancreas" (9,10). Therefore, equal access to diabetes technologies contributes to the humanization of diabetes treatment, in addition to its glycemic effects such as improving HbA1c and reducing the frequency and fear of hypoglycemia (9,11).

In Türkiye, a medium-income country, 70% of children with T1D have HbA1c over 7.5%, and 35% have HbA1c over 9% (75 mmol/mol) (12). Moreover, in the Southeastern Anatolia region, which is one of the least developed regions of Türkiye in various aspects, the prevalence of diabetic ketoacidosis (DKA) is 65.9%, 63% of which is severe DKA, and the frequency of DKA increases up to 87.5% between the ages of 0-4 (13). Despite the evidence and intense advocacy efforts over the last 5 years, Türkiye temporarily reimburses CGM for a limited number of children with T1D who meet strict criteria. Türkiye also provides partial reimbursement (approximately 20%) for insulin pumps. However, the prevalence of diabetes technology use and the characteristics of the population who have access are unknown. The aim of this study is to examine the use of diabetes technology in terms of socioeconomic groups and regions, and to investigate the determinants and inequalities of access to diabetes technologies. Our results may provide data to decision-makers in addressing inequalities in access to diabetes technology.

Methods

Participants

The study protocol was shared previously (14). In brief, parents of children and adolescents with type 1 diabetes were recruited from nine pediatric endocrinology centers and the Children Diabetes Foundation Network in Türkiye. The online survey was distributed to the parents during routine visits at the clinics and through the Children Diabetes Foundation's social media groups personally. Only mothers or fathers whose children were diagnosed with T1D before the age of 18 were included, caregivers other than the mother or father were excluded. Participants with a diabetes duration of less than 3 months were excluded to ensure the families had sufficient experience with T1D.

Questionnaire

Briefly, the Questionnaire covers the child's clinical and household sociodemographic characteristics, CGM and pump use, the latest HbA1c value, the education level of both parents, the working statuses of both parents, financial burden of diabetes (14). Only one parent completed the questionnaire, mostly mothers (77.6%), for the entire family. The Ethical Committee at Koç University approved the study (2022.378.IRB3.176) per the Declaration of Helsinki.

Statistical Analyses

The primary outcome of the study is the socioeconomic determinants of technology use. Technology use is divided into 4 categories: only CGM use, only pump use, both CGM and pump use, and no technology use.

Regarding the independent variables; 81 provinces of Türkiye were ranked in 6 groups based on socioeconomic development, according to the "socioeconomic development ranking of provinces research" of the Turkish Ministry of Industry and Technology (15). According to this ranking, we divided the provinces where the families were located into 6 groups and used 3 categories for analysis: the most developed region, the least developed region, and the remaining four groups as intermediate developed regions. The highest education levels of parents were analyzed in 3 categories: less than high school, high school, and university degree or above.

Descriptive statistics were presented as means with standard deviation or absolute numbers with percentages. For univariate analysis, one-way ANOVA and Kruskal-Wallis tests were used for continuous variables, chi-square test was used for categorical comparisons. A multinominal logistic regression model assessed technology use (only CGM users, only pump users, and both CGM and pump users compared with no technology use), adjusting for age, sex, region where the family lives (least/intermediate/most developed), education levels of mothers, education levels of fathers, number of working parents, and household income.

We conducted another analysis to evaluate which technology and which factors are associated with better glycemic outcomes in technology users. In this analysis, we assessed the factors associated with better glycemic control (lower HbA1c) in technology users (CGM and/or pump users). For this, a linear regression model used the HbA1c as the dependent variable and age, sex, diabetes duration, CGM use (Only pump use vs. CGM with or without pump use), the number of working parents, education levels of mothers, education levels of fathers, the region where the family lives, and household income as predictors. After forward stepwise variable selection, diabetes duration, the region where the family lives, education levels of mothers, CGM use, and household income were included in the model as predictors. IBM's SPSS version 28.0 was used for the analysis and p values <0.05 were considered significant.

Results

Study population

Of the 1254 responses, 372 were excluded due to missing information or duplicate responses. Among the final 882 responses, 692 were from 9 pediatric endocrinology clinics and 190 were from the online network of Children Diabetes Foundation. Participants were from 65 out of 81 provinces of Türkiye.

Participant families' characteristics are summarized in Table 1. Of 882 children with T1D (52.5% female, mean age 10.75 ± 4.6 years, diabetes duration 7 ± 3.8 years), 94% were living with both parents 53 children (6%) were with a single parent. While 75.5% of children had at least one sibling, 13% of them had a sibling with a chronic medical condition. Twenty-five families (2.8%) had more than one child with T1D.

According to self-reported 738 HbA1c values, the mean last HbA1c was 7.5% (58 mmol/mol). Reported current pump and CGM use were 19.4% and 49.7%, respectively. Of all children, 15% were using both pump and CGM, 4.4% using only pump, 34.7% using only CGM and 45.9% were not using any diabetes technology.

Technology use (CGM and/or pump use) was 16.1% in the least developed region, 67.8% in the intermediate developed region, and 66.1% in the most developed region. CGM use was 14.4%, 60.1%, and 62.5% in these regions, respectively while pump use was 3.6%, 27.8%, and 22.5%, respectively.

Characteristics of technology users and determinants of technology use

Family characteristics of only CGM users, only pump users, both pump and CGM users, and no technology users are shown in Table 2. Technology use did not differ by the sex and living arrangements of children (living with a single parent or both parents) (p=ns).

The number of siblings is higher in families that do not use technology in their children's diabetes care. No technology users had similar household incomes to only pump users but lower household incomes than CGM users; mother or father's education is lower, they have fewer working parents, they report less financial burden caused by diabetes, and they mostly live in the least developed region compared to those using CGM and/or pump (p<0.001 for all) (Table 2). Mean HbA1c levels by technology use are shown in Figure 1a. HbA1c was lower in CGM users among pump users (Both CGM and pump vs. only pump: 7.05% (54 mmol/mol) vs. 8.0% (64 mmol/mol), p<0.001) and insulin pen users (Only CGM vs. no technology: 7.07% (54 mmol/mol) vs. 8.07% (65 mmol/mol), p<0.001). However, HbA1c did not differ by pump use in CGM users (Both CGM and pump vs. only CGM: 7.05% (54 mmol/mol) vs. 7.07% (54 mmol/mol), p=0.868) and blood glucometer users (only pump vs. no technology: 8.00% (64 mmol/mol) vs. 8.07% (65 mmol/mol), p=0.810). HbA1c was lower in all regions by CGM use (Figure 1b).

To understand the social determinants of technology use, a multinomial logistic regression analysis was used. In this analysis, we assessed technology use (only CGM users, only pump users, and both CGM and pump users compared with no technology use), adjusting for age, sex, region (least/intermediate/most developed), education levels of mothers, education levels of fathers, number of working parents, and household income. The results showed that children living in the least developed region had lower odds of having only CGM (OR=0.20, 95% CI 0.12 – 0.34) and having both CGM and pump (OR=0.07, 95% CI 0.03 – 0.22) compared with living in the most developed region. Children with a mother who had not finished high school had lower odds of having only CGM (OR=0.36, 95% CI 0.19 – 0.66) or both CGM and pump (OR=0.27, 95% CI 0.11 – 0.64) rather than no technology compared to children whose mother has a university degree or above. Fathers' education levels had similar results for only CGM (OR=0.32 95% CI 0.18 – 0.60) and both CGM and pump users (OR=0.34 95% CI 0.15 – 0.79) rather than no technology users. Every 12000 Turkish Liras (□840 US dollars) increase in the household income increased the odds 5% for using CGM (OR=1.05, 95% CI 1.02 – 1.09) and both CGM and pump (OR=1.05 95% CI 1.01 – 1.08).

Factors associated with better glycemic control in technology users

After showing better glycemic management by technology use (Figure 1a), we performed a linear regression analysis to examine variables associated with glycemic control among 431 CGM and/or pump-user children, specifically to investigate the effect of single or multiple technology use.

The model is adjusted for diabetes duration, region where the family lives, mother's education level, technology use (CGM use only, pump use only, CGM and pump use), and household income. Living in the least developed region is associated with 0.54% (6 mmol/mol) higher HbA1c (95% CI 0.11% (1 mmol/mol) – 0.97% (11 mmol/mol), p=0.013) compared with living in the most developed region. Children whose mothers have up to high school degrees have 0.26% (3 mmol/mol) higher HbA1c (95% CI 0.01% (0.1 mmol/mol) – 0.51% (6 mmol/mol), p=0.04) than mothers with a university degree or above. Using only pump was associated with 0.57% (6 mmol/mol) higher HbA1c (95% CI 0.15% (2 mmol/mol) – 1.00% (11 mmol/mol), p=0.007) compared to CGM use with or without a pump. Twelve thousand Turkish liras (□840 US dollars) increase in household income was associated with a 0.02% (0.1 mmol/mol) decrease in HbA1c (95% CI 0.003% (0.1 mmol/mol) – 0.03% (0.1 mmol/mol), p=0.017). One year increase in diabetes duration was associated with a 0.05% (0.1 mmol/mol) increase in HbA1c (95% CI 0.015 (0.1 mmol/mol) – 0.087% (1 mmol/mol), p=0.006).

Discussion

Our study showed the inequality for access to diabetes technologies and associated socioeconomic determinants and some of those factors were also associated with better or worse glycemic management among technology users. The inequality in access to diabetes technologies has emerged as an important problem for children with diabetes, regardless of the socioeconomic development level of the countries, as shown in the United States and New Zealand (2,16). Our study, the first data published from Türkiye, shows significantly lower technology usage in underdeveloped regions than in intermediate and most developed regions, and the difference between regions is more prominent in pump usage. This more pronounced difference regarding pump use may be due to several factors such that CGM use is relatively easy, depending on individual preferences and skills, whereas pump use requires more skills and the presence of healthcare providers familiar with the use of technology.

It has been stated that access to health care results from the interface between the supply-side characteristics of health systems and organizations and the demand-side characteristics of populations (17). Similarly, in our study we showed that inequalities in access to diabetes technologies are multi-layered and they are not just related to affordability or coverage by reimbursement. Among those layers, population factors such as the education levels of parents, household income, and the working status of parents affected the inequality in access to diabetes technologies. However, there are health system related factors such as the supply and reimbursement of diabetes technologies, the number and availability of healthcare providers that are experienced with diabetes technologies. These structural layers of the inequality affect all individuals in a region regardless of individual factors. Thus, equitable access to technologies such as CGM and/or automatic insulin delivery systems requires programs that prioritize the most disadvantaged areas and consider the social determinants of health (5). In our results, there is a close parallel between household income, the educational level of the parents, and the number of working parents, moreover, these are collectively associated with access to technology.

Studies from New Zealand and Germany show that inequalities regarding type 1 diabetes care and metabolic control are not only socioeconomic but also barriers arising from ethnicity, language, and cultural differences (16,18). Another point that is as important as these obstacles is whether families who do not use this technology are aware of the existence and benefits of these technologies. Lack of awareness may be another factor associated with access to technology, as we did not obtain information from parents about whether they were familiar with diabetes technologies. Therefore, there is a need to evaluate the lack of awareness about technologies, social and cultural barriers related to language, mothers' education, and employment in the least developed regions in a separate study (19). A qualitative study emphasizes that inequalities have a complex structure involving people with diabetes, their families, and diabetes teams (20). The choices of people with diabetes are directed by their culture and beliefs which should be considered, and specific programs should be developed to reduce inequalities instead of blaming people with diabetes for their choices (20).

The most important paradox about diabetes technologies is that diabetes technologies are the most promising developments regarding the improvement of diabetes treatment, carry the risk of increasing inequalities both worldwide and within countries if the necessary measures are not taken (5). The reason for this is that in today's conditions, it is not the children who need it most, but those who are economically and socially advantaged that benefit most from these technologies. This situation also applies to Türkiye as shown in this study. We need to accept that this is unethical, and that socioeconomic inequalities and structural exclusionary processes have a critical importance on the health of children with diabetes. It seems that providing equal access to diabetes technologies from the diagnosis may be the first step in reducing the impact of inequalities on glucose management (8). Our study showed that CGM use in all regions results in lower HbA1c regardless of pump use, while the same effect is not valid for pump use. However, CGM use was associated with more socioeconomic factors. Therefore, in countries with limited economic opportunities, priority can be given to providing CGM to all children with diabetes (3).

The strengths of this study were the large number of families from all regions and meticulous data collection.

Study limitations

Cross-sectional study design, self-reported data, and unknown response rates were the limitations of this study. The fact that awareness about the existence of these devices and their benefits in diabetes care was not asked, which is one of the determinants of access to technologies, should be considered as another limitation.

Conclusion

In conclusion, there are inequalities to access to diabetes technologies such as the parent's education level, socioeconomic development of regions where families live, and household income. The inequalities are more prominent in access to CGM while CGM had a bigger contribution to the improvement in glycemic control. Thus, there is a need for specific initiatives to overcome disparities in technology access for children with T1D, especially those from disadvantaged socioeconomic backgrounds.

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Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.
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Table 1. Characteristics of participants

	All participant families (n=882)
Children	
Age, years, mean ± SD	10.75 ± 4.6
Sex, Female, n(%)	463 (52.5)
Diabetes duration, years, mean ± SD	3.7 ± 3.5
Child's living arrangement, n(%)	
With both parents	829 (94.0)
With a single mother	51 (5.0)
With a single father	2 (1.0)
Children with sibling(s), n(%)	666 (75.5)
Sibling(s) with chronic condition, n(%)[a]	86 (13.0)
Sibling with T1D, n(%)[a]	25 (2.8)
The last A1c, mean ± SD[b]	7.5 ± 1.4
Current use of CGM, n(%)	438 (49.7)
Current use of pump, n(%)	171 (19.4)
No technology users, n(%)	405 (45.9)
Parents, mother/father	
Parents' age, years, mean ± SD	39 ± 6.4 / 42.3 ± 6.8
Latest Educational qualification, n(%)/n(%)	
Less than high school	282 (32.0) / 227 (25.7)
High school graduate	221 (25.1) / 255 (28.9)
University degree or above	379 (43.0) / 400 (45.4)
Number of working parents, n(%)	
Both parents are not working	71 (8.0)
Only one parent is working	518 (58.7)
Both parents are working	293 (33.2)
The region where family lives, n(%)	
The least developed	222 (25.2)
Intermediate developed	273 (31.0)
The most developed	387 (43.9)

[a]Percentages were calculated for children with at least one sibling.
[b] HbA1c was self-reported from 738 responders.

Table 2. Technology use by the characteristics of children and families

	No technology users (n=405)	Only pump users (n=39)	Only CGM users (n=306)	Both pump and CGM users (n=132)	p
Age, years, Mean (SD)	11.5 ± 4.6[a]	13.8 ± 5.4[a]	9.1 ± 4.1[b]	11.3 ± 4.6[b]	<0.001
Sex, female, n(%)	216 (53.3)	24 (61.5)	149 (48.7)	74 (56.1)	0.279
Diabetes duration, years, Mean (SD)	3.9 ± 3.6[a]	6.7 ± 5.1[b]	2.6 ± 2.6[c]	5.0 ± 3.3[d]	<0.001
HbA1c, %, Mean (SD)	8.1 ± 1.6[a]	8.0 ± 1.4[a]	7.1 ± 1.2[b]	7.1 ± 1.0[b]	<0.001
Number of siblings, Median (IQR)	2 (1-3)[a]	1 (1-2)[b]	1 (0-1)[b]	1 (0-1)[b]	<0.001
Living arrangement, With both parents, n(%)	380 (93.8)	37 (94.9)	289 (94.4)	123 (93.2)	0.953
Household income, Turkish Lira/month, Median (IQR)	5000 (4000 - 7500)[a]	7000 (4250 - 10000)[a]	10000 (6500 - 18000)[b]	12000 (8000-20000)[b]	<0.001
Region where family lives, n(%)					<0.001
The least developed region	186 (45.9)	4 (10.3)	28 (9.2)	4 (3.0)	
Intermediate developed region	88 (21.7)	21 (53.8)	109 (35.6)	55 (41.7)	
The most developed region	131 (32.3)	14 (35.9)	169 (55.2)	73 (55.3)	
Education level of mothers, n(%)					<0.001
University degree or above	78 (19.3)	13 (33.3)	200 (65.4)	88 (66.7)	
High school graduates	110 (27.2)	15 (38.5)	64 (20.9)	32 (24.2)	
Less than high school	217 (53.6)	11 (28.2)	42 (13.7)	12 (9.1)	
Education level of fathers, n(%)					<0.001
University degree or above	99 (24.4)	10 (25.6)	206 (67.3)	85 (64.4)	
High school graduates	138 (34.1)	18 (46.2)	64 (20.9)	35 (26.5)	
Less than high school	168 (41.5)	11 (28.2)	36 (11.8)	12 (9.1)	
Number of working parent, n(%)					<0.001
Both parents working	76 (18.8)	9 (23.1)	135 (44.1)	73 (55.3)	
Only one parent working	272 (67.2)	27 (69.2)	162 (52.9)	57 (43.2)	
Both parents not working	57 (14.1)	3 (7.7)	9 (2.9)	2 (1.5)	
Financial loss due to diabetes care, n(%)					<0.001
No to minimal loss	80 (19.8)	2 (5.1)	24 (7.8)	7 (5.3)	
Moderate financial loss	126 (31.1)	13 (33.3)	97 (31.7)	27 (20.5)	
High to severe financial loss	199 (49.1)	24 (61.5)	185 (60.5)	98 (74.2)	

HbA1c was self-reported from 738 responders. Others were from 882 responses.
One way ANOVA, Kruskal-Wallis, or Chi-square tests are used when appropriate.
Subgroup comparison of continuous variables after Bonferroni correction were shown with superscript letters, while same superscript letters are not significantly different and different letters significantly differ.

Table 3. Variables related to only pump use, only CGM use, and both CGM and pump use by multinomial logistic regression analysis

	Only pump					**Only CGM**					**Both pump and CGM**				
			95% CI					95% CI					95% CI		
	Beta	OR	Lower	Upper	p-values	Beta	OR	Lower	Upper	p-values	Beta	OR	Lower	Upper	p-values
Age	0.1	1.11	1.03	1.19	**0.006**	-0.12	0.89	0.85	0.93	**<.001**	-0.01	0.99	0.95	1.05	0.82
Male vs. Female	-0.34	0.71	0.35	1.43	0.339	-0.04	0.96	0.66	1.39	0.827	-0.27	0.76	0.48	1.2	0.245
Household income, Turkish Lira[a]	0.03	1.04	0.99	1.08	0.128	0.05	1.05	1.02	1.09	**0.001**	0.05	1.05	1.01	1.08	**0.005**
Education level of mothers															
Less than high school vs. university degree or above	-1.11	0.33	0.1	1.04	0.059	-1.04	0.36	0.19	0.66	**0.001**	-1.31	0.27	0.11	0.64	**0.003**
High school vs. university degree or above	-0.35	0.71	0.27	1.88	0.489	-0.67	0.51	0.3	0.87	**0.013**	-0.46	0.63	0.33	1.19	0.157
Education level of fathers															
Less than high school vs. university degree or above	0.39	1.48	0.47	4.6	0.501	-1.13	0.32	0.18	0.6	**<.001**	-1.07	0.34	0.15	0.79	**0.012**
High school vs. university degree or above	0.65	1.91	0.74	4.92	0.182	-0.71	0.49	0.3	0.81	**0.005**	-0.39	0.68	0.37	1.23	0.2
Number of working parents															
Both parents working vs. both parents not working	-0.21	0.81	0.18	3.7	0.784	0.13	1.14	0.45	2.89	0.782	1.27	3.57	0.76	16.91	0.108
Only one parent working vs. both parents not working	0.46	1.59	0.43	5.83	0.489	0.37	1.45	0.62	3.38	0.39	1.11	3.03	0.67	13.68	0.15
Region where family lives															
The least developed vs. most developed	-1.11	0.33	0.1	1.08	0.067	-1.61	0.2	0.12	0.34	**<.001**	-2.61	0.07	0.03	0.22	**<.001**
Intermediate developed vs. most developed	0.96	2.62	1.22	5.62	**0.013**	0	1	0.66	1.53	0.984	0.18	1.2	0.74	1.95	0.463

Reference category is no technology users.
[a]A unit increase in household income is 12000 Turkish Liras (approximately 840 US dollars).

Figure 1: a- HbA1C levels by CGM and/or pump use, three technology categories were compared with no technology users. b – HbA1c levels by CGM use in the least, intermediate and most developed regions. * p<0.05, *** p<0.001