Impact of Artificial Intelligence Chatbots on Medication Adherence, Glycemic Control and Diabetes Distress among Adolescents with Diabetes Mellitus

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Abstract

Background: Numerous researchers have emphasized the potential advantages of artificial intelligence chatbots in managing diabetes and other chronic diseases. **Aim** of the present study was to evaluate the impact of artificial intelligence chatbots on medication adherence, glycemic control and diabetes distress among adolescents with diabetes mellitus. **Subjects and method:** this study was conducted at pediatric endocrinology clinic in Assiut University children's hospital, a pre-experimental research design (one group pre- post design) was used. This trial involved thirty children. Four tools were used to get the data of this study, **Tool I:** Background information form, **Tool II:** Medication adherence assessment tool, **Tool III**: Glycemic control level, **Tool IV:** Diabetes distress scale. The **results** of this study showed a statistically significant difference (p-value of 0.001**) between before and after the intervention regarding medication adherence, glycemic control and diabetes distress. The researchers **concluded** that implementation of artificial intelligence chatbots leads to a significant improvement in medication adherence rates, glycemic levels (e.g., HbA1c) and reduction in diabetes distress among adolescents with diabetes mellitus. The researchers **recommended** that integrate chatbots-based education into routine diabetes care and use chatbots in broader populations, including children with limited literacy, rural access issues, or other chronic conditions.

Keywords: Adolescents, Artificial intelligence, Chatbots, Diabetes Mellitus, Diabetes distress, Glycemic control, Medication adherence

Introduction

Diabetes mellitus (DM) is a long-term metabolic disease that necessitates intense medication compliance and lifestyle changes to avoid both immediate and long-term consequences. Due to social, psychological, and developmental factors, adolescents with diabetes, especially those with type 1 diabetes mellitus (T1DM), have a difficult time maintaining optimum glycemic control **(Chiang et al., 2018).** Non-adherence to recommended drugs and insulin therapy leads to poor disease outcomes, more hospitalizations, and a higher risk of long-term complications such as neuropathy, retinopathy, and cardiovascular diseases **(Hood et al., 2018).** Innovative and successful interventions are desperately needed to improve medication adherence, as the prevalence of diabetes among adolescents is increasing worldwide **(Kirkland et al., 2022).**

Adolescence is a crucial time for psychological and emotional changes that might affect medication adherence and other health-related behaviors. Adolescents with diabetes have poor adherence due to a number of factors, including mental discomfort, peer pressure, injection anxiety, forgetfulness, and lack of enthusiasm **(Maharjan et al., 2021)**. Traditional adherence techniques like parental supervision and healthcare provider interventions might not always work for this age group because of their desire for independence and autonomy. AI chatbots can offer a personalized approach with interesting, nonjudgmental, and tailored reminders that fit adolescents' communication preferences and lifestyles **(Kirkland et al., 2022)**.

Numerous researchers have emphasized the potential advantages of AI chatbots in managing diabetes and other chronic diseases. According to research, chatbots can enhance drug adherence by lowering obstacles to healthcare access, boosting patient engagement, and offering cognitive-behavioral therapies. To further increase adherence rates, AI-driven therapies can incorporate social support tools, gamification strategies, and real-time monitoring. But even with these encouraging results, more research is still needed to determine how well AI chatbots work, particularly when it comes to managing diabetes in adolescents **(Laranjo et al., 2018).**

Although AI chatbots have many benefits, they also have drawbacks and restrictions. Important factors to take into account while using chatbots include privacy concerns, data security challenges, and the requirement for frequent updates to ensure accuracy and relevance **(Schobel et al., 2020).** Furthermore, user involvement and trust which might differ across adolescents depending on their technology literacy, cultural background, and personal preferences are essential to chatbots efficacy **(Tschandl et al., 2020)**.

Significance of the study

Adolescents often face challenges in managing their condition due to emotional and social factors, which can lead to poor health outcomes. AI chatbots can provide personalized support, real-time monitoring, and educational resources, making it easier for young individuals to adhere to their treatment regimens while also addressing the emotional burden associated with diabetes (**Maharjan et al., 2021).** The integration of AI chatbots in diabetes care aligns with the growing trend of digital health interventions. As mobile health (mHealth) applications become more prevalent, understanding the potential benefits and limitations of AI chatbots is crucial for optimizing care of diabetic children **(Laranjo et al., 2018).** So, this study was conducted to evaluate the impact of artificial intelligence chatbots on medication adherence, glycemic control and diabetes distress among adolescents with diabetes mellitus

Aim of study

The aim of this study was to:

Evaluate the impact of artificial intelligence chatbots on medication adherence, glycemic control and diabetes distress among adolescents with diabetes mellitus**.**

This aim was achieved through these objectives:

- To measure the adherence rates to prescribed medication regimens among adolescents using AI chatbots.
- To analyze changes in glycemic levels (e.g., HbA1c) in adolescents who engage with AI chatbots for diabetes management.
- To explore the impact of AI chatbots on the diabetes-related distress.

Hypotheses of the study:

Hypothesis 0: The use of artificial intelligence chatbots has no significant impact on medication adherence, glycemic control, and diabetes distress among adolescents with diabetes mellitus.

Hypothesis I: Adolescents with diabetes mellitus who use artificial intelligence chatbots demonstrate higher medication adherence rates.

Hypothesis II: The implementation of artificial intelligence chatbots can improve glycemic levels (e.g., HbA1c) among adolescents with diabetes mellitus.

Hypothesis III: Adolescents with diabetes mellitus utilizing artificial intelligence chatbots report lower levels of diabetes distress.

Hypothesis IV: Improvement in medication adherence leads to improvement in glycemic control levels.

Materials and methods:

Research design:

In the present study, a pre-experimental research design (one group pre- post design) was used.

Setting: This study was conducted at the pediatric endocrinology clinic in Assiut University children's hospital which located at the first floor. This clinic is open on Mondays and Wednesdays each week from 8:00 a.m. to 2:00 p.m.

Subjects: A purposive sample of 30 children with diabetes was selected from the previously mentioned setting.

Inclusion criteria:

1. Adolescents aged 12–18 years diagnosed with diabetes mellitus (primarily type 1).
2. Currently prescribed insulin therapy requiring regular adherence.
3. Willing to use an AI-powered chatbot for medication reminders and diabetes management.
4. Access to a smartphone, tablet, or other digital device capable of running the chatbot application.
5. Adolescents had the cognitive ability to understand and respond to chatbot interactions, typically assessed through basic literacy and comprehension skills.

Sample size:

The necessary sample size for this study was determined based on the calculations outlined by **(Thompson, 2012)** from the next formula:

$$n = \frac{Nx\, p\,(1-p)}{[[N - 1x\,(d^2 \div z^2)] + p\,(1-P)]}$$

Where:
n: sample size (?)
N: Population size (35)
Z: Confidence level at 95% (1.96)
d: Error proportion (0.05)
p: Probability (50%)

According to this formula the total sample size was 30 which mean that a minimum of 30 children is needed to collect the data of this study.

Tools: Four tools were used to collect the data of this study:

Tool I: Background information form: which consisted of two parts:

Part one: Demographic characteristics of the studied children including age, gender, educational level and residence.

Part two: Medical data of the studied children including duration of diabetes diagnosis, family history of diabetes and insulin self-administration.

Tool II: Medication adherence assessment tool:

Morisky Medication Adherence Scale (**MMMS):** a validated 8 items questionnaire to assess the extent of medication adherence **(Morisky, et al., 2008).**

MMAS-8 Questions:
Participants respond with "Yes" (0 point) or "No" (1 point)

1. Do you sometimes forget to take your diabetes medication؟
2. In the past two weeks, were there any days when you did not take your diabetes medication?
3. Have you ever reduced or stopped taking your medication without telling your doctor?
4. When you travel or leave home, do you sometimes forget to bring your medication?
5. Did you take your diabetes medications exactly as prescribed in the last week?
6. Do you find it difficult to remember to take all your diabetes medications?
7. Have you skipped medication doses because you felt better?
8. Have you skipped medication doses because you felt worse?

Scoring system:

- High Adherence (Score: 8), which means the child follows their medication regimen consistently.
- Medium Adherence (Score: 6–7), which means some non-adherence behavior is present but not severe.
- Low Adherence (Score: ≤5), which means Significant non-adherence, indicating a need for intervention

Tool III: Glycemic control level (Hood et al., 2009):

Latest HbA1c level: ______ %

- < 7.0% (Good)
- 7.0% – 8.9% (Moderate)
- ≥9.0% (Poor)

Tool IV: Diabetes distress scale (Polonsky et al., 2005): A tool to measure distress related to diabetes management, 17 items covering four key of diabetes related distress.

Each item is rated on a 4-point Likert scale:
0 = Not a problem
1 = A slight problem
2 = A moderate problem
3 = A serious problem

Domains and Sample Questions

A. Emotional distress (7 items)

1. Feeling overwhelmed by the demands of living with diabetes.
2. Feeling that I am failing with my diabetes routine.
3. Feeling that diabetes controls my life.
4. Feeling that I will never be able to manage diabetes as well as I would like.
5. Not feeling motivated to keep up with my diabetes care.
6. Feeling angry, scared, or depressed when thinking about living with diabetes.
7. Feeling discouraged about how diabetes management is going.

B. Physician related distress (2 items)

1. Feeling that my doctor doesn't understand what I go through.
2. Feeling that I don't receive enough help from my doctor.

C. Regimen related distress (4 items)

1. Feeling that I am not sticking closely enough to my meal plan.
2. Feeling that I am not testing my blood sugar levels frequently enough.
3. Feeling that I am not keeping my diabetes as controlled as I should be.
4. Feeling that my diabetes is taking up too much of my mental and physical energy.

D. Interpersonal distress (4 items)

1. Feeling alone with my diabetes.
2. Feeling that my family and friends do not give me the emotional support I would like.
3. Feeling that friends or family don't appreciate how difficult living with diabetes can be.
4. Feeling that friends or family don't give me the help I need.

Scoring system:

Add up the scores for all 17 items then divide the total by 17 to get the average distress score.

- Little or No Distress (Score < 2.0): Minimal emotional burden.
- Moderate Distress (Score 2.0–2.9): Some psychological challenges that may affect self-care.
- High Distress (Score ≥ 3.0): Significant emotional distress.

Method

1. An official permission was obtained from the director of Assiut University Children's Hospital to collect the necessary data for this study from the pediatric endocrinology clinic.
2. A pilot study was carried out on 10% of children (3) to test the clarity and applicability of the sheet and to estimate the time needed to fulfill each sheet, and the necessary modification was done, and the final form was developed, and this sample was excluded from the total sample of the study.
3. Tools of the study were developed by the researchers and were tested for their content validity by 5 experts in both pediatric nursing and pediatric surgery fields, and it was 97%.
4. Tools reliability was done using the alpha Cronbach test and it was 0.972 for tool II, 0.986 for tool III and 0.965 for tool IV.
5. Data was collected using the designed tools from the study and control groups.

Field of the work:

Beginning in February 2025 and ending in April 2025, this study was conducted over a period of three months. Two times per week, the researchers went to the hospital. Data was collected from the same group before the intervention and after the intervention.

Procedure for gathering data:

1. Baseline Assessment (before the intervention data collection)

The researchers introduced themselves to the children and their family member, fulfilling study criteria, and explained the aim of the study. The written informed consent was obtained from each child's family member after a complete description of the purpose and the nature of the study, and then the researchers filled out the data collection sheets through a direct interview on an individual basis, the researchers take every child's phone number and add it to the WhatsApp group, which took about 30 minutes.

2. Implementation of AI Chatbots Intervention

Children were trained on how to use the AI chatbots, which provided the following:

- Medication reminders
- Diabetes education
- Behavioral support
- Encouragement messages

The chatbots was available via mobile application. Children were used the Chabot for 8 weeks while continuing their usual diabetes care, researchers make sure children continue to use chatbots through WhatsApp group.

3. Follow-up assessment (after the intervention data collection)

After the intervention period, children underwent reassessment using the same tools as the baseline assessment.

Ethical Considerations:

The director of the Children University Hospital officially approved the study after it was reviewed and approved by the Ethics Committee of the Assiut University Faculty of Nursing under the number 1120251096. It was followed by the submission of a formal letter detailing the study's objectives. Next, make sure that every participant understands the aim, benefits, and methods of data collection of this study. It was explained to the participants that they can pause at any moment without incurring any penalties and that their participation was completely voluntary. Next, signed consent was requested from the family members of each child included in this study. All data collected would be kept strictly confidential and used only to advance the objectives of the study.

Statistical analysis

Data were collected, coded, revised and entered to the Statistical Package for Social Science (IBM SPSS) version 22. The data were presented as number and percentages, mean & standard deviations. Chi-square test and paired sample t -test were used to compare the variables.

Results:

Table (1): Presents distribution of the studied children according their demographic characteristics (N=30), it was found that less than two third (60%) of the studied children aged between 12 and <14 years, with a mean age of 11.04 ± 3.43 years. Regarding gender, more than half (53.3%) of the studied children were male, while less than half of them (46.7%) were female, (63.3%) of the studied children resided in urban areas. In terms of education, half of the studied children (50%) were in secondary school.

Table (2): Shows distribution of the studied children according their medical data (N=30). A notable proportion (43.3%) had been diagnosed with diabetes for less than 5 years, while one-third (33.3%) had lived with the condition for 10 years or more. A strong family history of diabetes was observed in 80% of the children. Additionally, 73.3% of the children were independently administering insulin.

Figure (1): Illustrates medication adherence in the studied children before and after intervention. It was found that less three quarters of the studied children (70%) had a high medication adherence after the intervention, while less than two third of them (60%) have low medication adherence before the intervention with a highly statistically significant difference (p-value =0.001**).

Table (3): Illustrates level of glycemic control before and after the intervention. The proportion of children achieving good glycemic control (<7%) increased markedly from 30% before the intervention to 66.7% after the intervention (p=.001), indicating a statistically significant enhancement. Conversely, the percentage of children with poor control (>9%) decreased from 36.7% to 20% with a highly statistically significant difference (p-value =0.001**).

Figure (2): Displays diabetes distress level in the studied children before and after the intervention. It was detected that more than three quarters (83.3%) of the studied children had little or no distress after the intervention, while less than one third of them (30%) had high distress with a highly statistically significant difference (p-value =0.001**).

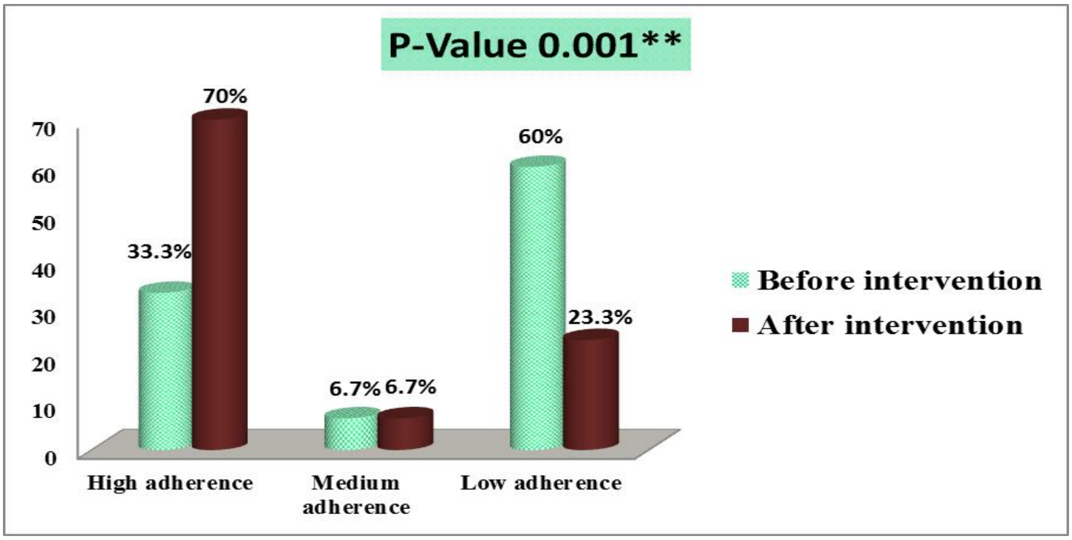
Table (4): examines the relationship between medication adherence and glycemic control level before and after the intervention. In both before and after the intervention, higher adherence was associated with better glycemic control with a highly statistically significant difference (p-value =0.001**).

Table (1): Distribution of the studied children according to their demographic characteristics (N=30)

Variable	Study group (N=30)	
	No.	%
Child age		
12-<14 yrs.	18	60
14-<16 yrs.	10	33.3
16- 18 yrs.	2	6.7
Mean + SD	**11.04 + 3.43**	
Gender		
• Male	16	53.3
• Female	14	46.7
Residence		
• Urban	19	63.3
• Rural	11	36.7
Education		
• Primary	6	20.0
• Preparatory	9	30.0
• Secondary	15	50.0

Table (2): Distribution of the studied children according to their medical history (N=30)

Variable	(N=30)	
	No.	%
Duration of diabetes diagnosis		
< 5yrs	13	43.3
5-<10 yrs.	7	23.3
10 yrs. or more	10	33.3
Family history of diabetes		
• Yes	24	80.0
• No	6	20.0
Insulin self-administration		
• Yes	22	73.3
• No	8	26.7



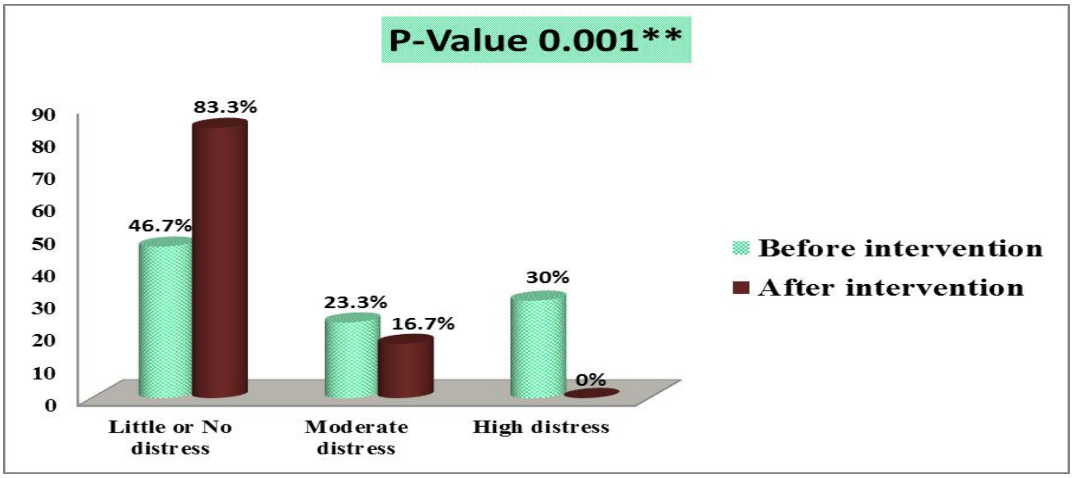
Paired sample t-test

Figure (1): Medication adherence in the studied children before and after the intervention

Table (3): Level of glycemic control level in the studied children before and after the intervention (N=30)

level of glycemic control	Before intervention		After intervention		P-value
	No.	%	No.	%	
• Good (<7%)	9	30.0	20	66.7	0.001**
• Moderate (7-8>9%)	10	33.3	4	13.3	
• Poor (> 9%)	11	36.7	6	20.0	

Chi-square test
(**) Highly statistically significant difference



Paired sample t-test

Figure (2): Diabetes Distress level in the studied children before and after the intervention

Table (4): Relationship between medication adherence and glycemic control level before and after the intervention

Medication adherence	Glycemic control level Before intervention						P-value	Glycemic control level After intervention						p-value
	Good		Moderate		Poor			Good		Moderate		Poor		
	N	%	N	%	N	%		N	%	N	%	N	%	
High adherence	9	100	1	10	0	0	**0.001****	11	55	4	100	0	0	**0.001****
Medium adherence	0	0	8	80	1	9.1		7	35	0	0	0	0	
Low adherence	0	0	1	10	10	90.9		2	10	0	0	6	100	

Chi-square test
(**) Highly statistically significant difference

Discussion:

Diabetes mellitus in children presents significant challenges due to the lifelong need for insulin therapy, strict self-management, and the psychological burden it imposes on both children and families. Innovative strategies, such as AI Chatbots, have gained attention for their potential to support diabetes management through accessible, interactive, and personalized support **(Sun et al., 2021).** So, this study aimed to evaluate the impact of artificial intelligence chatbots on medication adherence, glycemic control and diabetes distress among adolescents with diabetes mellitus.

In this study, children show a high level of medication adherence after the intervention with a highly statistically significant difference (p-value =0.001**). The researchers explained that chatbot used in the present study may have had similar motivational components, such as encouraging messages and tailored feedback, which are known to enhance adherence by increasing self-confidence and reducing resistance to treatment

These results are in the similar line with **Schoenthaler et al., 2018** in their systematic review which show that interactive text messaging significantly improved medication adherence in individuals with chronic conditions also, **Klee et al., 2016** in their study which examine a mobile app designed for adolescents with T1DM and reported increased medication adherence and frequency of self-monitoring. **Clement et al., 2016** evaluated a digital adherence support tool and found that its improved insulin dose accuracy and timing in pediatric patients in addition to **Mulvaney et al. 2012** who found that a motivational text-based program improved medication adherence and self-management skills among adolescents with T1DM.

These studies corroborate the results of the present study and reinforce the importance of adherence-focused interventions in improving pediatric diabetes outcomes. High adherence after the intervention is likely due to the reminder function and interactive engagement provided by the AI chatbots. Adolescents respond well to digital interfaces that resemble social platforms they already use. The AI chatbots may have improved understanding of the importance of insulin timing and dosage; the intervention may have addressed forgetfulness and emotional resistance, two common reasons for poor adherence, by offering gentle daily prompts and encouragement and this finding supported the researchers' first hypothesis.

In the current study, glycemic control improved after the intervention, with a highly statistically significant difference (p-value =0.001**). This finding is consistent with multiple studies that evaluated technology-based interventions in pediatric diabetes care, **Sun et al., 2021** conducted a meta-analysis involving over 2,000 children and adolescents with T1DM and found that digital interventions reduced HbA1c by an average of 0.34%, emphasizing their value in improving glycemic outcomes. **Zhang et al., 2020** implemented a WeChat-based chatbot for adolescents in China and reported that 62.5% of users achieved target HbA1c (<7.5%) after three months, compared to 35% at baseline. **Casey et al. 2019** assessed a diabetes-specific smartphone application and found that 68% of adolescents improved their HbA1c levels significantly over 12 weeks of engagement.

These consistent improvements across studies support the current findings and highlight the potential of AI chatbots to positively influence metabolic outcomes in pediatric diabetes care. The significant improvement in glycemic control post-intervention may be attributed to the increased knowledge and motivation provided by the AI chatbots. The AI chatbots likely enhanced the children's confidence in managing their disease, leading to better control and this finding supported the researchers' second hypothesis.

In this study, children showed a marked decrease in diabetes distress after the intervention with a highly statistically significant difference (p-value =0.001**). These results are consistent with those obtained by **Kaliisa et al., 2023** demonstrated that an AI chatbot provided stress-reducing support, with adolescent users reporting a significant drop in distress scores after 8 weeks also, **Streisand et al. 2019** evaluated a mobile intervention for parents of children with T1DM and found that improved parental coping and reduced stress translated to lower distress in children.

The reduction in distress in the current study may be attributed to the chatbot's consistent communication, nonjudgmental feedback, and emotional support, features validated in the literature as effective in mitigating diabetes-related emotional challenges. Children and adolescents with T1DM often experience anxiety, burnout, and fear of complications. Chatbots provide immediate, empathetic, and private support, which can relieve emotional burden and this finding, supported the researchers' third hypothesis.

In this study, high medication adherence was significantly associated with improved glycemic control both before and after the intervention with a highly statistically significant difference (p-value =0.001**). These results are in the similar line with **Hood et al., 2009** who found a strong correlation between adherence to insulin therapy and HbA1c levels in children with T1DM, emphasizing that better adherence predicted better metabolic control this finding supported the researchers' fourth hypothesis.

Conclusion:

The researchers concluded that implementation of artificial intelligence chatbots leads to a significant improvement in medication adherence rates, glycemic levels (e.g., HbA1c) and reduction in diabetes distress among adolescents with diabetes mellitus. Furthermore, improvement in medication adherence leads to improvement in glycemic control levels.

Recommendations:

1. Integrate chatbots-based education into routine diabetes care.
2. Encourage pediatric nurses and diabetes educators to utilize digital tools such as chatbots to deliver consistent, child-friendly education, medication reminders, and emotional support.
3. Conduct long-term studies to evaluate the sustained impact of chatbots interventions on adherence, glycemic control, and psychosocial outcomes.
4. Use chatbots in broader populations, including children with limited literacy, rural access issues, or other chronic conditions.

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