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ORIGINAL PAPER

# Preferences of type 1 diabetes individuals for continuous glucose monitoring (CGM) system features

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## ABSTRACT

**Introduction:** Continuous glucose monitoring (CGM) systems have become a key tool in diabetes therapy, enabling patients to monitor glucose levels in real-time. This study aimed to identify the most important features of CGM systems for people with diabetes (PwD).

**Material and methods:** A survey conducted by a research team consisting of diabetologists, psychologists, and diabetic patients was addressed to PwD to explore their preferences for CGM systems. The study was conducted from March 24 to April 15, 2023. Study group consisted of Facebook users of forums related to diabetology and CGM systems. Also, PwD or their caregivers, who attended appointments at the diabetic clinic of Upper Silesian Child Health Centre in Katowice, Poland, were included. A total of 498 correctly completed surveys were collected, and data were analyzed in terms of financial aspects, sensor replacement frequency, calibration, compatibility with other devices, notifications, and system size.

**Results:** According to the results, financial structure of CGM systems users varied, with parents and younger patients more likely to choose higher monthly expenses (56.2%). A preference was noted for sensor replacement every 14 days (59.4%) and calibration-free systems (75.7%). The system was highly preferred for integration with smartphone apps (95.2%) and compatibility with insulin pumps (65.3%). In addition, notifications of current glucose levels were considered a key feature of a CGM system, with most users preferring glucose variability alerts (96.8%).

**Conclusions:** Patients select CGM systems based on their personal needs and preferences, prioritizing features, such as user-friendliness, smartphone compatibility, sensor lifespan, and ability to share data with caregivers. Also, cost, design, and clinical benefits influence their choices.

KEY WORDS:

**diabetes, patient preferences, continuous glucose monitoring, CGM systems, CGM system personalization.**

## INTRODUCTION

Over the past two decades, diabetes treatment has been revolutionized by the introduction of continuous glucose monitoring (CGM) systems, which have since become an integral part of diabetes management [1]. These systems allow for monitoring changing glucose levels, enabling people with diabetes (PwD) to make effective and safe therapeutic decisions about insulin dosing, diet, and lifestyle [2].

Despite their advantages, successful use of CGM systems requires, among other things, careful selection of the type of system and adaptation to each patient's individual needs. Currently, numerous CGM systems are available, varying in accuracy, data presentation, sensor lifespan, need for calibration, integration with insulin

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pumps, applications, and cost to an individual or health insurer.

The variety of available CGM systems can make it challenging for PwD to choose the most suitable one. However, the wide range of options allows for finding a device that closely matches an individual's specific medical and personal needs.

In Poland, the access to CGM systems has recently become widespread, mainly due to expanded reimbursement rules introduced in January 2023. The expansion of CGM systems' availability highlights the importance of patient education and support in selecting and using the appropriate device [3]. Considering the varied range of available CGM systems and limited number of publications on this topic, the authors conducted the study on the personalization of CGM systems for PwD. This study aimed to analyze users' choices to determine the most preferred features based on various parameters of CGM systems.

## MATERIAL AND METHODS

A questionnaire was distributed within the study group consisting of users of Facebook forums related to diabetology and CGM systems. Additionally, patients or their caregivers attending appointments at the diabetic clinic of Upper Silesian Child Health Centre in Katowice, Poland, were included. The study population comprised individuals with diabetes, irrespective of diabetes' type or treatment modality. Significantly, all participants were current users of CGM systems. The aim was to assess which features and functionality characteristics of CGM systems were perceived as the most essential by users, or considered desirable for future system development. This questionnaire-based study was conducted from March 24, 2023 to April 15, 2023, and participation in the study was voluntary and anonymous.

An original, researcher-developed questionnaire was created by a team of diabetologists, psychologists, and diabetic patients. The questionnaire consisted of 38 questions divided into 5 thematic blocks: (1) verification of knowledge about the essence of a CGM system; (2) basic information on the user or legal guardian who completed the form (age, gender, amount of fluids consumed per day, insulin pump utilization); (3) previous use of CGM systems; (4) user preferences for CGM systems; and (5) knowledge about CGM systems.

Users of all ages could complete the survey, but in children, parent or caregiver provided answers on the behalf of an youngster. Parents and legal guardians constituted 48.2% of the respondents.

The participants were divided into two primary groups, with their responses differing according to level of reimbursement available. This variability was associated with age of an individual with diabetes, as the reimbursement eligibility age threshold is set at 26 years. Additional age group divisions were established based on potential differences in preferences and usage patterns of CGM systems, which may be influenced by age-related factors. Age can affect the acceptance of new technologies, health management behaviors, and financial priorities. This stratification allows for a more precise analysis and comparison of user preferences within more homogeneous groups.

This study was approved by Institutional Ethical Committee of the Medical University of Silesia, Katowice, Poland (approval number: BNW/NWN/0052/KB/170/23).

**TABLE 1.** Distribution of respondents by continuous glucose monitoring (CGM) systems' costs across age groups

| Value (PLN) | Percentage of respondents (%) |
|---|---|
| Distribution by cost of CGM system among respondents aged up to 26 years | |
| 100–150 | 27.1 |
| 200–300 | 38.6 |
| Price not significant | 18.4 |
| Distribution of by cost of CGM system among respondents aged above 26 years | |
| 100–200 | 52.3 |
| 350–400 | 30.1 |

## RESULTS

A total of 498 surveys with fully completed information were collected. All participants in the study were users of CGM systems. The respondents were divided into 10 age categories.

Table 1 presents the percentage distribution of respondents' preferred monthly expenditure related to the use of CGM systems. Part 1 refers to PwD aged 26 years or younger (64.5%), while part 2 relates to individuals over the age of 26 years (35.5%). In the group of those aged over 26 years, the response option "regardless of price" for the purchase of a CGM system was intentionally excluded from the results, as none of the respondents in this group selected this option.

Regarding sensor duration, the study showed that 59.4% of the respondents preferred the 14-day sensor option, while only 11.2% selected the 180-day sensor. The 7-day sensor responses were excluded from the analysis, as participants focused primarily on selecting their preferred sensor duration without considering other system features. Consequently, the 7-day option was chosen by a very small number of respondents.

The preference for avoiding finger pricking reflected in the desire to use a calibration-free system was expressed by 75.7% of the participants. For 95.2% of the respondents, compatibility of a CGM system with a smartphone was considered important, while for 65.3%, integration with an insulin pump was indicated significant.

The analysis showed that notifications about current glucose's levels, essential for using CGM systems, play

a crucial role for 96.8% of the users. In CGM systems, alerts indicate high and low glucose levels, rate of their increase and decrease, and predictions of high and low glucose levels. Trend arrows, which indicate changes in glucose trends, are also shown in notifications. A decisive majority of the respondents (range, 87.8–98.6%) valued the presence of alarms.

The final criterion was the size of a CGM system, perceived in terms of esthetics and usability. A total of 85.7% of the individuals preferred the system to be as small as possible and to fit closely to the body.

In the final question summarizing the patient preferences, the respondents indicated comfort (60%), compatibility with the application (59.4%), notifications (56.6%), price (56.2%), and sensor duration (53.8%) as the most critical features.

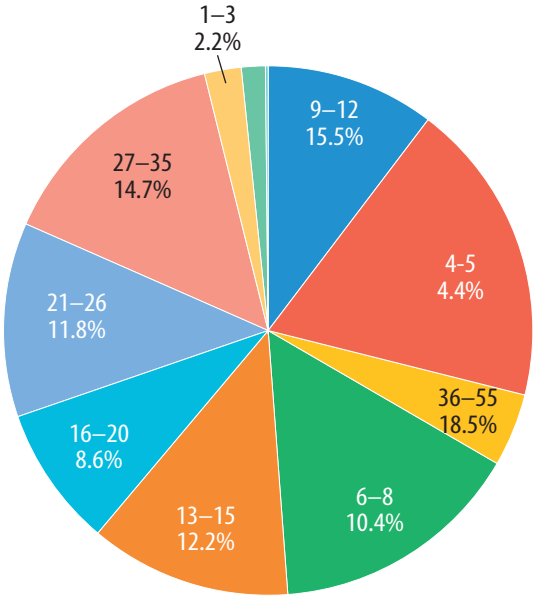


**FIGURE 1.** Age of respondents (years)

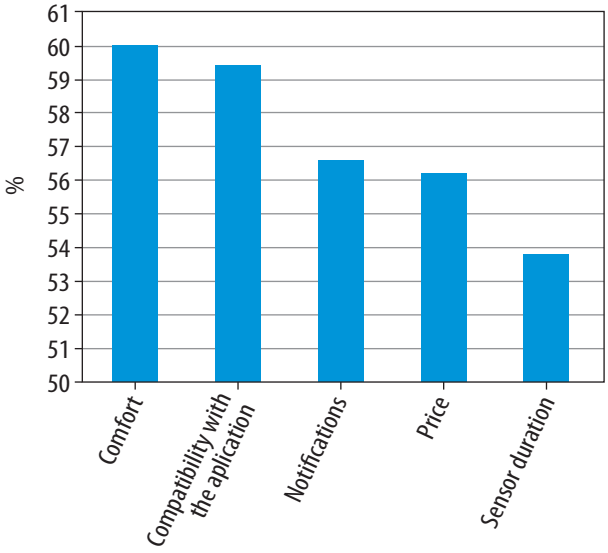


**FIGURE 2.** Five most important parameters of continuous glucose monitoring (CGM) systems for patients, including comfort, compatibility with mobile application, notifications, price, and sensor operating time

## DISCUSSION

To the authors' knowledge, there is little research on users' preferences for CGM systems in the available literature. The survey presented in this article is the first attempt in Poland to objectively analyze the needs and preferences for utilization of CGM systems.

According to the current Polish and international recommendations, i.e., the Polish Diabetes Association (PTD), the American Diabetes Association (ADA), and the International Society for Pediatric and Adolescent Diabetes (ISPAD), the CGM system is the recommended tool for glucose monitoring [3], supporting safe self-management and contributing to improved outcomes and quality of life.

### PRICE

Based on the conducted survey, the financial structure of the users was highly diversified [4]. In the analysis of financial variability between the two designated groups of patients, it was observed that among participants under the age of 26 years, the cost of purchasing and maintaining a CGM system was not high compared with the group of users aged over 26 years. This observed trend may be related to the respondents completing the survey. In the case of minors, the survey could have been completed by their parents, who comprised almost half of the participants. This interpretation suggests that parents of children with diabetes tend to choose systems of the highest quality, with the greatest convenience and safety of use.

Given the price, CGM systems should be accessible to as many patients as possible, regardless of their financial situation [5]. One potential solution is the broader implementation of financial regulations through increased reimbursement of CGM systems [6]. As a result, buyers would not have to consider the price when choosing a system, allowing them to focus on most critical aspects, such as comfort of use or app's compatibility. The introduction of such regulations could be crucial for improving the availability and financial accessibility of CGM systems, which, in turn, could contribute to increased utilization in diabetes treatment and improved patient quality of life.

### SENSOR DURATION

The results of the study showed a dominant user's preference for sensors that are replaced every 14 days [7]. This trend suggests that patients are limited in choosing systems, which offer this replacement frequency. As is well-known, these sensors are the easiest to apply

and operate, and are very minimally invasive compared with other options available on the market. Most PwD expressed the opinion that the system should be accurate and easy to use, which refers to the simplicity of applying or operating the sensor, and the ease of using a smartphone app and basic alerts, supporting treatment decision-making.

An important observation is that a tiny percentage of patients indicated 180-day sensor despite the growing trend of extending sensor's lifespan. This result most likely shows that patients are aware of the sensors' high invasiveness [8], as they are implanted subcutaneously and require specialist assistance during their use. In addition, they are very expensive and well beyond financial capabilities of patients. On the other hand, this may be due to the lack of PwD's knowledge or no trust in such a long-lasting sensor. Overall, the difficulties associated with the use of 180-day sensors contradict the needs of patients, which can explain such low interest in these sensors among PwD.

Unfortunately, in Poland, CGM systems integrated with insulin pumps currently offer an operating time shorter than 14 days, posing a challenge for patients who want to meet their preferences for pump compatibility and sensor longevity [1]. They are forced to choose a feature that is more important to them. However, it should be noted that companies are constantly expanding the compatibility of systems with insulin pumps, which is a positive trend in increasing patient comfort.

## CALIBRATION-FREE CGM, INTEGRATION WITH AN INSULIN PUMP AND APP

The study results indicate that the lack of a calibration with registration for treatment decision is a highly desirable system feature. Calibration-free CGM systems, though allowing for therapeutic decisions, offer several benefits, including eliminating the need for regular calibration, which can be convenient for users and reduce disruptions caused by frequent system calibration [9]. PwD want to live their lives as comfortably as possible, focusing minimally on their illness. Removing the need for calibration allows for greater freedom and convenience in life, avoiding excessive finger pricking or regular blood sampling. These systems permit to even forget about the need for finger pricking in some users.

Another advantage is that the calibration-free feature eliminates human errors, as too few or too many calibrations can result in either a deficiency or excess of information for the algorithm calculating glucose level in the interstitial fluid. Any disturbances in the algorithm's function can lead to inaccuracies in glucose readings.

Despite the convenience of calibration-free systems, it is surprising that 25% of patients chose systems that require calibration. This is due to the low level of trust in CGM systems; therefore, there must be systems that still offer the option of calibration, allowing patients to influence the performance profile by entering additional data into the system.

Regarding patient comfort, it is important to underscore the system compatibility with smartphone apps [10]. Integrating CGM functionality into smartphones allows patients to manage their diabetes in an increasingly simple and convenient way. It was found that accessing their phone is much easier for patients than searching for a special receiver to monitor their glucose levels, which is how CGM systems have been monitored until recently. This feature enhances quality of life and reduces expenses related to purchasing a CGM system by eliminating the need to buy a separate receiver. However, purchasing a separate receiver can sometimes be less expensive than purchasing a compatible phone. It should also be noted that for some people, operating applications on a smartphone is a complicated task, so it is encouraging that some systems allow for using a dedicated receiver.

Additionally, a common complication when using applications is the phone's operating system update, which often prevents or disrupts the proper functioning of application. Advanced integration of CGM systems with mobile apps [11] permits users and their therapeutic partners [12, 13] to receive notifications on their smartphones on glucose changes and trends. According to the study results, patients truly need collaboration and real-time alerts. It was also observed that patients are eager to share their data with care partners, and feel safer under their supervision [14].

Unfortunately, only a limited number of CGM systems are integrated with insulin pumps [15]. Therefore, CGM systems must be compatible with these devices, enabling users to fully utilize their functionalities and benefits.

In relation to the latest guidelines from PTD, ADA, and ISPAD, the most appropriate therapy is the use of closed-loop systems, which require cooperation with CGM systems.

Furthermore, patients are forced to make separate choices due to compatibility limitations. A common view among patients is that they choose a closed-loop system, but are dissatisfied with a CGM or express low satisfaction with the insulin pump.

## NOTIFICATION

The analysis results indicate that notifications [16] regarding current glucose levels are extremely important for CGM system users. Almost all the respondents considered them a crucial part of using these systems. These notifications cover a wide range of information related to various aspects of glucose levels. Additionally, trend arrows, indicating the direction and rate of glucose changes, are also considered valuable data by users. It is worth noting that the vast majority of respondents emphasized

the importance of alerts in CGM systems. These alerts play a crucial role in warning users of potential risks, such as significant increases or decreases in glucose levels [17].

The current CGM systems include notifications, which play a critical role in diabetes management. These alerts have been shown to improve patients' convenience and quality of life. By relying on notifications, individuals can reduce the frequency of direct glucose checks. If no alert is triggered, they can assume their glucose levels are stable; when a notification does appear, it immediately captures the patient's attention, prompting timely therapeutic action. These alerts lessen the need for constant monitoring and help patients stay aware of glucose trends. This increased focus enables quicker responses, leading to improved therapeutic outcomes.

In the study, a larger percentage of respondents highlighted the importance of low-glucose notifications compared with high-glucose alerts, confirming a general tendency to be more concerned about hypoglycemia [18, 19].

### SIZE AND ESTHETICS

The last discussed criterion, the size of a CGM system, is an important aspect of how customers evaluate these technologies in terms of esthetics and usability. The analysis results clearly indicate that for the vast majority of respondents, the system must be as small as possible and fit closely to the body. Although esthetic considerations may seem less important than functionality, their significance should not be underestimated. Esthetic and discreet appearance of a system can affect users' well-being and confidence, especially in social situations where they prefer to avoid discomfort related to visibility of the device [20]. Additionally, a smaller system size can contribute to better usability, providing a less cumbersome wearing experience [21]. However, it is important to note that minimizing the system's size should not come at the cost of its functionality or reliability. Despite smaller dimensions, the system must remain efficient and accurate in its measurements, to provide users with the necessary data for effective diabetes management.

## STRENGTHS AND LIMITATIONS

### STRENGTHS

This study significantly contribute to understanding of user preferences for CGM systems, particularly in the Polish healthcare context. A key strength is the large and diverse sample of 498 fully completed surveys, with respondents from both online diabetic forums and the Upper Silesian Child Health Centre, offering broad representation across age groups and treatment types. This diversity enhances the generalizability of the findings.

The study design is robust, with a detailed questionnaire created by a multidisciplinary team of diabetologists, psychologists, and diabetic individuals. This ensures a comprehensive capture of factors, including financial considerations, sensor preferences, and system compatibility. The focus on practical features, such as sensor lifespan, calibration, and device integration, provides actionable insights for improving CGM systems.

Another strength is the integration of user preferences with healthcare policy implications, highlighting the importance of patient education and reimbursement mechanisms in improving CGM accessibility and usability.

### LIMITATIONS

Despite its strengths, the study has some limitations. One main constraint is the reliance on self-reported data, which can lead to recall and response biases, potentially misrepresenting real-world behaviors and preferences.

Additionally, the cross-sectional design prevents establishing causal relationships between user preferences and clinical outcomes. While it highlights the features that PwD prioritize, it does not explore how these preferences affect long-term health outcomes, such as glycemic control or quality of life.

Sample selection is another limitation, as the online survey may exclude those less familiar with digital platforms or with limited technology access, introducing selection bias. The sample's focus on Facebook forum users and a specific clinic might not fully represent the broader PwD population in Poland.

Finally, while the findings are relevant to Poland, their generalizability to other countries or regions may be limited due to differences in healthcare systems, reimbursement policies, and cultural attitudes towards diabetes technology. Future studies should replicate this research in various regions to improve external validity.

## CONCLUSIONS

This study provides valuable insights into the factors shaping users' preferences for CGM systems, offering a clear framework for manufacturers, healthcare providers, and policy-makers to improve CGM design and implementation. The findings highlight the need to prioritize features, which enhance convenience, usability, and accessibility; these factors are crucial for better clinical outcomes and long-term adherence to diabetes management. In light of the study, the role of healthcare professionals, particularly diabetologists, should encompass an individualized selection of CGM system based on the patient's age, lifestyle, technological proficiency, and financial capacity. Clinicians are not only expected to present the available options, but also to actively guide patients through the decision-making process. This includes comprehensive explanation of key features of a system, such as sensor wear duration, requirement

for calibration, integration with insulin pump therapy, and compatibility with mobile applications.

Moreover, clinicians should continuously assess patients' understanding of CGM technology and provide targeted education regarding proper system use, maintenance, and clinical interpretation of glucose data. The importance of real-time alerts and appropriate responses to glycemic trends should be emphasized, as they are critical for timely therapeutic interventions.

Given the rapidly evolving technological landscape, healthcare professionals must also serve as informed advisors, staying up-to-date with current market innovations and clinical guidelines issued by national and international diabetes associations. Their responsibility is to recommend the most safe, effective, and patient-appropriate CGM solution, thereby fostering therapeutic engagement and contributing to improved metabolic control and quality of life.

In summary, these findings support the need for patient-centered strategies in the design, reimbursement, and clinical implementation of CGM systems. From the users' perspective, the highest priority is given to comfort, ease of use, device integration, and affordability, factors that are essential for long-term adherence and optimal diabetes management outcomes.

## DISCLOSURES

1. Institutional review board statement: This study was approved by Institutional Ethical Committee of the Medical University of Silesia, Katowice, Poland (approval number: BNW/NWN/0052/KB/170/23).
2. Assistance with the article: None.
3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

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