Patient Preference and Adherence

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Understanding Suboptimal Insulin Use in Type 1 and Type 2 Diabetes: A Cross-Sectional Survey of People with Diabetes

Rachel S Newson[1], Esther Artime[2], Julie Bower[3], Erik Spaepen[4], Birong Liao[3], Indranil Bhattacharya[5], Tadej Battelino[6]

[1]Medical Affairs, Eli Lilly and Company, Sydney, New South Wales, Australia; [2]VEO, Eli Lilly and Company, Alcobendas, Community of Madrid, Spain; [3]Medical Affairs, Eli Lilly and Company, Indianapolis, IN, USA; [4]HaaPACS GmbH, Schriesheim, Baden-Württemberg, Germany; [5]Medical Affairs, Eli Lilly and Company, Gurgaon, Haryana, India; [6]University Medical Center Ljubljana, and Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia

Correspondence: Rachel S Newson, Real World Evidence, Eli Lilly and Company, 60 Margaret Street, Sydney, NSW, 2000, Australia, Email newson_rachel@lilly.com

Purpose: This analysis aimed to document suboptimal insulin dosing (missed or skipped and mistimed basal and/or bolus) in people with diabetes (PwD), including type 1 diabetes (T1D) and type 2 diabetes (T2D). Additionally, barriers and solutions for optimal insulin dosing were explored.

Patients and Methods: This multinational, cross-sectional, online survey was conducted in the United States, the United Kingdom, and Germany. Eligible PwD with T1D or T2D used an analog insulin pen. Data were analyzed using descriptive statistics.

Results: A total of 1150 PwD (T1D: 300; T2D: 850) were included. Overall, a proportion of PwD reported missing 1 or more basal (48.2%) or bolus dose (59.6%) in the past 30 days. Among those who reported missing doses, the average number [standard deviation] was 3.6 [3.6] basal doses and 4.6 [7.4] bolus doses. PwD reported forgetting, being too busy/distracted, and finding it too complicated or burdensome as key reasons for missed doses. A proportion of PwD reported mistiming 1 or more basal (45.7%) dose or bolus (53.6%) dose in the past 30 days. Among those who reported mistiming doses, the average was 3.9 [4.0] basal and 5.1 [8.1] bolus doses. Key reasons reported for mistiming doses included being too busy or distracted, being out of routine, or having an unexpected or earlier/later-than-expected meal.

Conclusion: Suboptimal insulin use is prevalent among PwD, with nearly half of participants reporting missed or mistimed doses in the past 30 days. Results indicate the need for support to help PwD self-manage the complexity of insulin treatment and to improve outcomes due to suboptimal insulin dosing. Such support might include devices that record measurements and dosing and provide feedback.

Keywords: diabetes, basal, bolus, suboptimal dosing, missed doses, mistimed doses

Introduction

Diabetes mellitus, a disease affecting more than 422 million people worldwide,[1] continues to pose a global health problem with 9.3% of adults between the ages of 20 and 79 currently living with the disease.[2] The prevalence of diabetes is projected to increase, affecting approximately 643 million people by 2030 and 783 million by 2045, as reported by the International Diabetes Federation.[3] Diabetes remains one of the top 10 causes of death globally; 6.7 million diabetes-related deaths occurred in 2021, which translates to 1 death every 5 seconds.[3] Despite encouraging developments in diabetes-related therapeutics and innovations, the complexities of reaching levels of glycemic control continue to pose a challenge among people with diabetes (PwD).[4–8]

Achieving target glycemic control and maintaining concordance with insulin treatment are critical for treating diabetes and have been reported to reduce the risk of all-cause mortality and hospitalization in PwD.[9] Key reasons associated with poor adherence include misunderstanding the benefits associated with treatment; the complexity of treatment, including polypharmacy and variable dosing quantity and frequency; and fear of adverse effects such as hypoglycemia, weight gain, and gastrointestinal side effects.[9] A significant number of people with type 1 diabetes (T1D)

Received: 11 December 2024
Accepted: 8 May 2025
Published: 31 May 2025

or type 2 diabetes (T2D) are faced with challenging insulin regimens as prescribed, impeding optimal management of diabetes and resulting in poor health outcomes.[10] In 2012, Peyrot et al reported results from the Global Attitudes of Patients and Physicians study, an online multinational study conducted with healthcare professionals (HCPs) and a telephone survey with PwD who were treated with insulin. Results from the Global Attitudes of Patients and Physicians study showed that glucose control was inadequate among insulin-treated patients due to insulin omission or non-adherence and lack of dose adjustment.[11] The Global Attitudes of Patients and Physicians 2 study showed that suboptimal (missed, mistimed, and reduced) basal insulin dosing is a common challenge, and is frequent enough to negatively impact management of the disease.[12] In 2021, Robinson et al reported results from a systematic literature review showing that PwD struggle with self-management of insulin treatment, resulting in suboptimal insulin use. Given the pervasiveness of this problem, Robinson et al results suggest a need for integrated support for managing insulin therapy, including digital support as a potential solution to empower PwD to manage diabetes.[13] Despite innovations in insulin therapy and device technology, suboptimal dosing continues to be a barrier to achieving glycemic control for PwD, leads to frustrations and challenges, and increases the risk of diabetes complications.[13,14]

Results from these previous studies contributed to the impetus and development of the study described here, as a need remains to clarify the extent of suboptimal insulin dosing based on participant experience and geographic location, and to provide potential reasons and solutions. Hence, the primary objective of this study was to understand the extent of suboptimal insulin dosing in PwD with T1D and T2D, and to report reasons associated with suboptimal dosing and barriers to achieving optimal dosing from the perspective of PwD. In addition, this study examined potential solutions to improve optimal insulin dosing.

Materials and Methods

Study Design

This online survey study consisted of 2 phases, the pilot phase and the main study. During the pilot phase, a draft survey was distributed to a small sample of people with T1D (n = 3) and T2D (n = 3), and physicians (n = 4) in the United States for in-depth testing focused on survey comprehension. After the completion of the survey, participants were interviewed on survey usability. Subsequently, the survey was revised based on participants' feedback, and this version was used in the main study (Supplementary Materials). Data collection for the pilot phase took place between June and July of 2021.

The main study was a multinational, cross-sectional, online survey conducted with people (N = 1150) from the United States, the United Kingdom, and Germany between November 2021 and February 2022. Country selection was based on the feasibility of data capture and the extent of insulin experience. Here, we report results from PwD pooled across each country. The study was conducted using purposive sampling from existing online patient panels accessed via a third party. The study enrolled PwD ≥18 years of age who self-reported T1D or T2D, as diagnosed by a doctor, and used an analog insulin pen. A screener was implemented to check the diagnosis. People with T1D had a multiple daily insulin injection regimen (basal and bolus), and people with T2D had either a basal-only regimen or a basal and bolus regimen. Soft recruitment quotas per country were applied to the study to maximize the generalizability of the findings, which included recruiting a maximum of 75.0% Caucasian PwD. In addition, soft recruitment quotas relevant to clinical characteristics for PwD included up to 25.0% PwD who had <7.0% HbA1c, up to 25.0% PwD who did not know their HbA1c; up to 25.0% PwD who were diagnosed <6 months ago, and up to 25.0% PwD who used an insulin pen for <6 months. Exclusion criteria included current use of a connection-enabled pen system, cap, or sleeve.

Endpoints analyzed included the proportion of PwD who used basal and/or bolus insulin and missed or skipped insulin doses due to skipping a meal or other unrelated reasons. In addition, the study examined the mistiming of basal and/or bolus insulin doses and the reasons associated with mistiming doses. Participants completed an online survey (Supplementary Materials) that included a disease screening, questions regarding demographics, disease history, insulin use, barriers to dosing, interactions with HCPs, and unmet needs, such as the need for support with timing and recording of doses. All sections of the online study were programmed to collect only completed answers from participants, as participants were unable to skip or continue to the next question until each question was finished thereby preventing missed data. The following definitions were used as terms in the survey. Bolus refers to insulin that was either short-acting insulin or rapid-acting insulin taken at mealtimes. Basal was defined as intermediate or long-acting insulin taken

once or twice daily to manage blood sugar levels between meals. A missed insulin dose was defined as a missed or skipped insulin dose whereby participants did not either intentionally or unintentionally take a dose that they were scheduled to take. A mistimed dose was defined as any insulin dose that was taken at an incorrect time (for example, not within 10 to 15 minutes before a meal for bolus insulin, or not at the usual time for basal insulin).

Eligible participants provided consent using an electronic informed consent form completed online prior to the administration of any study procedures. Participants received remuneration in accordance with local fair market value rates in each country. This study was conducted in accordance with the ethical principles in the Declaration of Helsinki, consistent with Good Pharmacoepidemiology Practices, and applicable laws and regulations of the countries where the study was conducted. Centralized ethical approval and oversight of the pilot and main study phases were provided by the Ethical & Independent (E&I) Review Service (pilot study phase: E&I Study Number 2105-01, approved on 03-Jun-2021; and main study phase: E&I Study Number 21052-01A, approved on 16-Nov-2021).

Statistical Analysis

Survey responses were analyzed using descriptive statistics. Continuous variables were summarized using mean and standard deviation (SD) for normal distributions or median and range for skewed distributions. Categorical variables were summarized as numbers and percentages. Missing data were not possible because the survey was programmed such that a participant could not move on to the next question before completing the previous item. In the event a participant terminated before completing the survey, they were not counted as part of the study population. All statistical analyses were performed using SAS version 9.4 (The SAS Institute, Cary, NC).

Results

Participant and Diabetes Management Characteristics

The study included 1150 participants, consisting of 300 people (26.1%) with T1D and 850 people (73.9%) with T2D (Table 1). The mean [SD] age of PwD was 49.4 [13.4] years; 57.8% of PwD were male. The majority of PwD were Caucasian (85.4%),

Table 1 Baseline and Clinical Characteristics, n (%)

	Total, N = 1150
Demographics	
People with type 1 diabetes	300 (26.1)
People with type 2 diabetes	850 (73.9)
Age, years, mean [SD]	49.4 [13.4]
Female	482 (41.9)
Race/ethnicity	
White	982 (85.4)
United States	300 (75.0)
United Kingdom	312 (89.1)
Germany	370 (92.5)
Black or African American	109 (9.5)
United States	81 (20.3)
United Kingdom	14 (4.0)
Germany	14 (3.5)
Hispanic or Latino	96 (8.3)
United States	35 (8.8)
United Kingdom	19 (5.4)
Germany	42 (10.5)
Asian	13 (1.1)
United States	6 (1.5)
United Kingdom	7 (2.0)
Germany	0 (0.0)

(*Continued*)

https://doi.org/10.2147/PPA.S511332

Table 1 (Continued).

	Total, N = 1150
Native Hawaiian or other Pacific Islander	1 (0.1)
United States	1 (0.3)
United Kingdom	0 (0.0)
Germany	0 (0.0)
American Indian or Alaskan Native	8 (0.7)
United States	7 (1.8)
United Kingdom	1 (0.3)
Germany	0 (0.0)
Other[a]	5 (0.4)
United States	1 (0.3)
United Kingdom	1 (0.3)
Germany	3 (0.8)
Prefer not to say	3 (0.3)
United States	1 (0.3)
United Kingdom	0 (0.0)
Germany	2 (0.5)
Diabetes-related characteristics	
Time since diabetes diagnosis	
<6 months	103 (9.0)
6–12 months	101 (8.8)
1–5 years	347 (30.2)
5–10 years	222 (19.3)
>10 years	377 (32.8)
Time using insulin pen	
<6 months	118 (10.3)
6–12 months	152 (13.2)
1–2 years	316 (27.5)
>2 years	564 (49.0)
Most recent HbA1c	
<7% (<152 mg/dL)	229 (19.9)
7.1%–8% (153–183 mg/dL)	365 (31.7)
8.1%–9% (184–212 mg/dL)	425 (37.0)
>9% (>212 mg/dL)	90 (7.8)
I do not recall/do not know	41 (3.6%)
Hypoglycemic events in last 12 months, mean [SD]	4.7 [5.6]
Severe hypoglycemic events in last 12 months, mean [SD]	1.8 [2.8]
Diabetes complications within last 12 months	
Skin	154 (13.4)
Eye	327 (28.4)
Neuropathy	218 (19.0)
Nephropathy	123 (10.7)
Foot	156 (13.6)
Diabetic ketoacidosis	232 (20.2)
High blood pressure	295 (25.7)
Stroke/ischemic heart disease/heart attack	30 (2.6)
Less severe complications (eg, gum disease, slower healing)	158 (13.7)
None of the above	281 (24.4)

Notes: Data are n (%) unless otherwise specified. [a]Other ethnic racial background included: No other racial/ethnic backgrounds text description provided.
Abbreviation: SD, standard deviation.

Table 2 Information and Discussions with Healthcare Professionals, n (%)

	Total, N = 1150
Healthcare professional/provider responsible for treatment	
General practitioner	241 (21.0)
Endocrinologist	202 (17.6)
Diabetologist	647 (56.3)
Diabetes nurse	58 (5.0)
Other	2 (0.2)
Frequency of appointments with main healthcare provider	
Once or more per month	258 (22.4)
Once every 2–3 months	596 (51.8)
Once every 4–6 months	190 (16.5)
Every 6 months or less	106 (9.2)
Do you discuss missing insulin doses, taking too low doses, or taking doses too early or late with your HCP?[a]	
Yes	475 (41.3)
No	335 (29.1)
Missing	340 (29.6)
How comfortable are you discussing missing insulin doses, taking too low doses, or taking doses too early or late with your HCP?[a]	
Extremely uncomfortable	11 (1.0)
A little uncomfortable	59 (5.1)
Neutral	144 (12.5)
Comfortable	296 (25.7)
Extremely comfortable	300 (26.1)
Missing	340 (29.6)

Notes: [a]This survey question was only given to respondents who indicated they had missed/mistimed/miscalculated doses.
Abbreviation: HCP, healthcare professional.

married (74.4%), and worked as full-time employees (63.3%). A total of 31.2% of PwD reported earning a bachelor's degree, 18.8% reported earning a master's degree, and 17.7% reported earning an associate degree/professional certification.

Nine percent of PwD reported being diagnosed less than 6 months ago, 8.8% reported being diagnosed 6–12 months ago, 30.2% reported being diagnosed between 1–5 years ago, 19.3% reported being diagnosed 5–10 years ago, and 32.8% reported being diagnosed more than 10 years ago. Nearly half of PwD (49.0%) reported using an insulin pen for more than 2 years. The largest category of PwD (37.0%) reported that the most recent HbA1c level measured was between 8.1–9.0%. Within the last 12 months, the mean [SD] number of reported hypoglycemic events managed without help and severe hypoglycemic events was 4.7 [5.6] and 1.8 [2.8], respectively.

PwD reported different types of healthcare providers involved in their management of insulin treatment. Over half of PwD (56.3%) reported receiving insulin treatment from a diabetologist (Table 2). The majority of PwD (74.2%) reported the frequency of appointments with their main healthcare provider to be at least once every 2 to 3 months.

Basal Insulin

Of the total number of PwD, most participants (70.5%) received 1 basal insulin dose per day, while 29.5% received 2 doses per day.

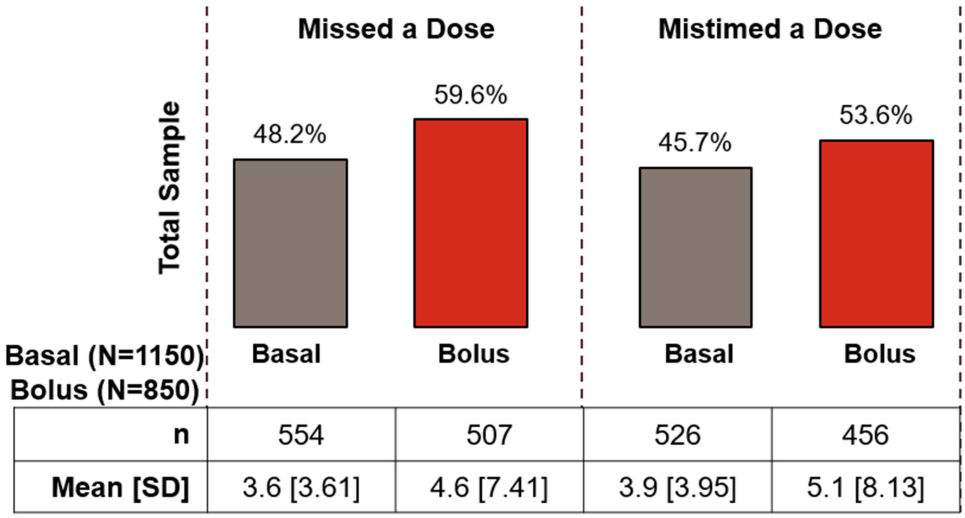
Missed or Skipped Basal Doses

In the past 30 days, nearly half of PwD (48.2%) reported at least 1 missed or skipped basal dose, with a mean [SD] of 3.6 [3.6], quartiles (1st, median, 3rd) of 1.0, 2.0, and 5.0, and a range of 1.0 to 30.0 (Table 3 and Figure 1). In the past 30

Table 3 Extent of Missed and Mistimed Insulin Doses

	Total, N = 1150
Daily basal doses, n (%)	
1	811 (70.5)
2	339 (29.5)
Missed or skipped basal doses in the past 30 days[a]	
n (%)	554 (48.2)
Mean [SD]	3.6 [3.6]
Q1 | median | Q3	1.0 | 2.0 | 5.0
Min, max	1.0–30.0
Mistimed basal doses in the past 30 days	
n (%)	526 (45.7)
Mean [SD]	3.9 [4.0]
Q1 | median | Q3	1.0|3.0|5.0
Min, max	1.0–44.0
PwD using bolus insulin of any type, n (%)	850 (73.9)
Type of bolus insulin, n (%)	
Rapid-acting	720 (84.7)
Ultra-rapid-acting	122 (14.4)
Do not know	2 (0.2)
Other	6 (0.7)
Daily bolus doses, n (%)	
1	195 (22.9)
2	219 (25.8)
3	315 (37.1)
4	73 (8.6)
5	31 (3.6)
≥6	17 (2.0)
Missed or skipped bolus doses in the past 30 days	
n (%)	507 (59.6)
Mean [SD]	4.6 [7.4]
Q1 | median | Q3	1.0|2.0|5.0
Min, Max	1.0–90.0
Missed or skipped bolus doses on purpose due to skipped meal	
Yes	159 (31.4)
Mean [SD]	3.7 [4.5]
Q1 | median | Q3	1.0 | 2.0 | 4.0
Min, Max	1.0–31.0
Mistimed bolus doses[b]	
n (%)	456 (53.6)
Mean [SD]	5.1 [8.13]
Q1 | median | Q3	2.0|3.0|5.0
Min, max	1.0–120.0

Notes: [a]PwDs with 0 missed or skipped basal insulin doses did not contribute to this table [b]PwD with 0 mistimed insulin doses and T2D sample PwD taking basal only did not contribute to the summary statistics.
Abbreviations: Max, maximum; Min, minimum; SD, standard deviation.



n	554	507	526	456
Mean [SD]	3.6 [3.61]	4.6 [7.41]	3.9 [3.95]	5.1 [8.13]

Figure 1 Extent of missed and mistimed insulin doses in the last 30 days. Nearly half of PwD reported missed or skipped and mistimed basal and bolus doses in the past 30 days.
Abbreviations: PwD, people with diabetes; SD, standard deviation.

days, 45.7% of PwD reported mistimed basal doses with a mean [SD] of 3.9 [4.0], quartiles (1st, median, 3rd) of 1.0, 3.0, and 5.0, and a range of 1.0 to 44.0.

The most frequent reasons PwD reported missed or skipped basal doses were: forgetting (34.1%), being too busy and/or distracted (24.9%), and finding it too complicated and burdensome (24.0%) (Figure 2). Additional reasons included:

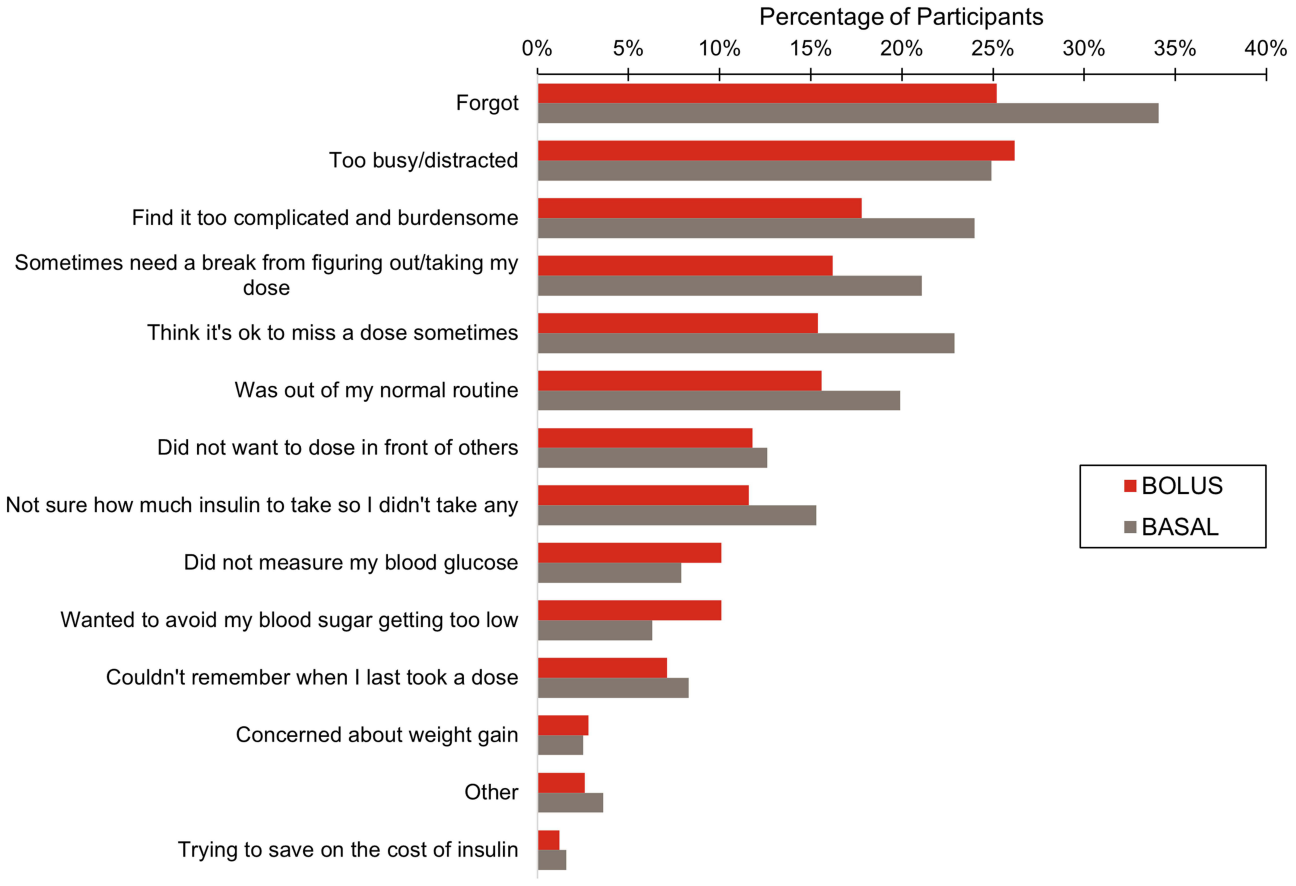


Figure 2 Reasons reported for missed or skipped insulin dose. The most frequent reasons PwD reported missed or skipped basal and bolus doses were: forgetting, being too busy and/or distracted, and finding it too complicated and burdensome.
Abbreviation: PwD, people with diabetes.

https://doi.org/10.2147/PPA.S511332

finding it acceptable to miss a dose sometimes (22.9%), sometimes needed a break from figuring out/taking a dose (21.1%), being out of normal routine (19.9%), not being sure of how much insulin to take so not taking any (for example, being sick, exercising, unfamiliar food, not having insulin plan available) (15.3%), not wanting to dose in front of others (12.6%), not remembering when last dose was taken (8.3%), not measuring blood glucose level (7.9%), wanting to avoid blood sugar getting too low (6.3%), other reason (3.6%), being concerned about weight gain (2.5%), and trying to save on the cost of insulin (1.6%).

Mistimed Basal Doses

PwD were surveyed on their experience with mistimed basal insulin doses. A substantial proportion of PwD (45.7%) reported mistiming their basal doses (Figure 1). The mean number of mistimed basal insulin doses reported by PwD in the past 30 days was 3.9 [4.0], quartiles (1st, median, 3rd) of 1.0, 3.0, and 5.0, and a range of 1.0 to 44.0.

The top 5 reasons reported by PwD that caused the mistiming of basal insulin doses for the total PwD population included: being too busy/distracted (25.7%), being out of normal routine (24.7%), forgetting (24.3%), not being sure how much insulin to take due to unfamiliar food (23.0%), and not wanting to dose in front of others (22.2%) (Figure 3).

Bolus Insulin

Bolus insulin of any type was used by (850/1150) 73.9% of PwD, and the majority of participants (720/850; 84.7%) reported using rapid-acting bolus insulin for treatment. The largest proportion of PwD were those (436/850; 51.3%) who reported receiving 3 bolus insulin doses per day, while (219/850) 25.8% of PwD reported receiving 2 doses per day, and (195/850) 22.9% of PwD reported receiving 1 daily bolus dose per day.

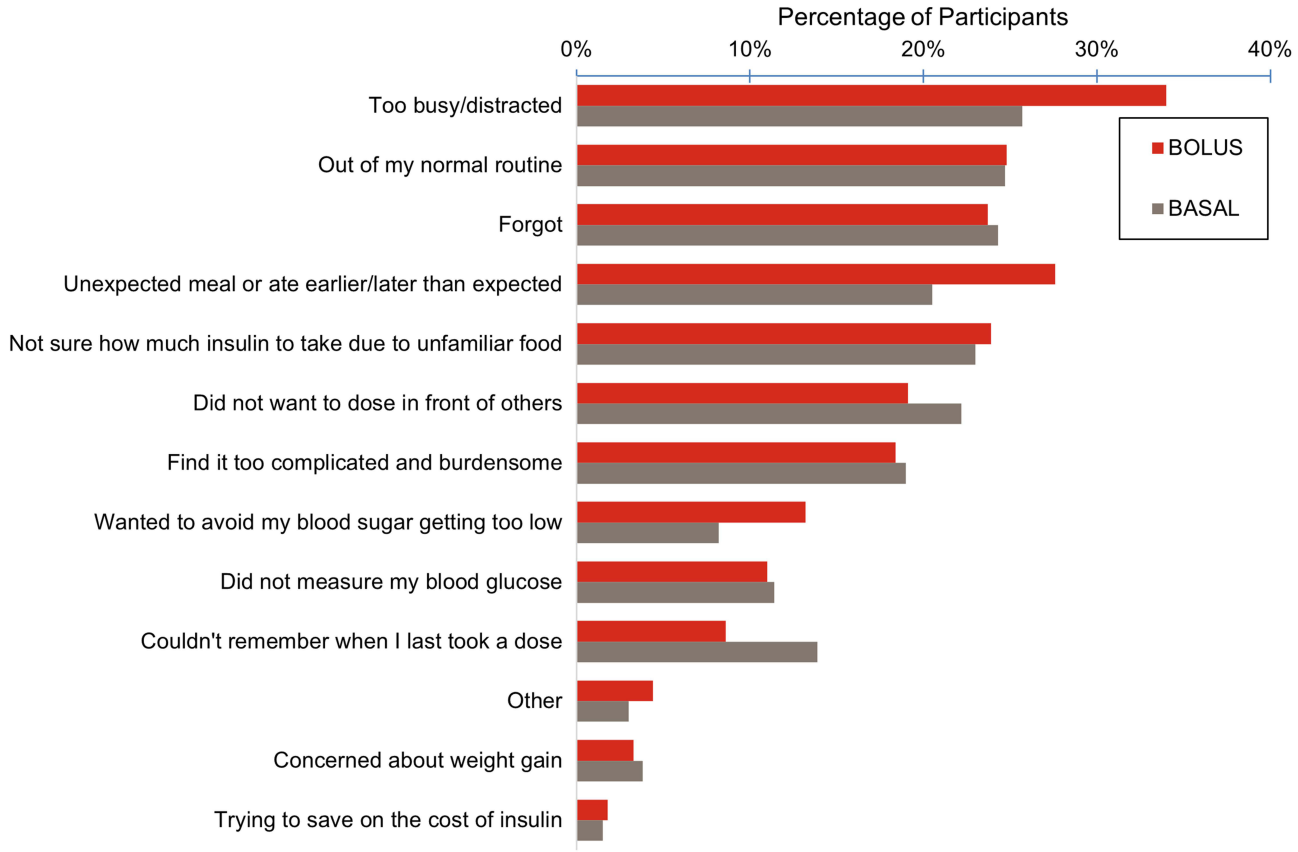


Figure 3 Reasons PwD reported mistiming an insulin dose. Participants were surveyed on the main reasons that contributed to mistimed basal and bolus insulin doses.
Abbreviation: PwD, people with diabetes.

Missed or Skipped Bolus Doses

More than half of PwD (59.6%) using bolus insulin reported missed or skipped bolus doses (Figure 1 and Table 3). In the past 30 days, the mean [SD] number of bolus doses missed or skipped by PwD was 4.6 [7.4], quartiles (1st, median, 3rd) of 1.0, 2.0, and 5.0, and a range of 1.0 to 90.0. In total, 31.4% percent of PwD reported making a choice to miss or skip bolus doses due to skipping a meal, with a mean [SD] number of 3.7 [4.5], quartiles (1st, median, 3rd) of 1.0, 2.0, and 4.0, and a range of 1.0 to 31.0.

PwD who missed or skipped bolus doses reported the same most frequent reasons as PwD reported for missed or skipped basal doses, which included: forgetting (25.2%), being too busy and/or distracted (26.2%), and finding it too complicated and burdensome (17.8%) (Figure 2). Additional reasons reported by PwD included: sometimes needed a break from figuring out/taking doses (16.2%), finding it okay to miss a dose sometimes (15.4%), being out of normal routine (15.6%), not wanting to dose in front of others (11.8%), not being sure how much insulin to take so not taking any (for example, being sick, exercising, unfamiliar food, not having insulin plan available) (11.6%), not measuring blood glucose level (10.1%), wanting to avoid blood sugar getting too low (10.1%), not recalling when last dose was taken (7.1%), concerned about weight gain (2.8%), other reason (2.6%), and trying to save on the cost of insulin (1.6%).

Mistimed Bolus Doses

PwD were surveyed on their experience with mistimed insulin bolus doses, and more than half of PwD (53.6%) reported mistiming their bolus doses (Figure 1). The mean number of mistimed bolus insulin doses reported by PwD was 5.1 [8.13], quartiles (1st, median, 3rd) of 2.0, 3.0, and 5.0, and a range of 1.0 to 120.0 (Table 3).

Participants were surveyed on the main reasons that contributed to mistimed bolus insulin doses (Figure 3). Approximately one third of the total PwD (34.0%) reported the reason was due to: being too busy/distracted, while 27.6% of PwD had an unexpected meal or ate earlier or later than expected, and a quarter of participants (24.8%) reported that the mistimed dose was caused by being out of a normal routine. Nearly a quarter of PwD (23.9%) reported not being sure how much insulin to take due to unfamiliar food, and 23.7% reported forgetting.

Barriers

Even though 78.7% of PwD reported they agreed or strongly agreed that their insulin dose was taken as prescribed, and that they felt somewhat confident (46.0%) or extremely confident (42.0%) about managing insulin within the past 12 months, many PwD reported several difficulties associated with insulin management (Figure 4). PwD were

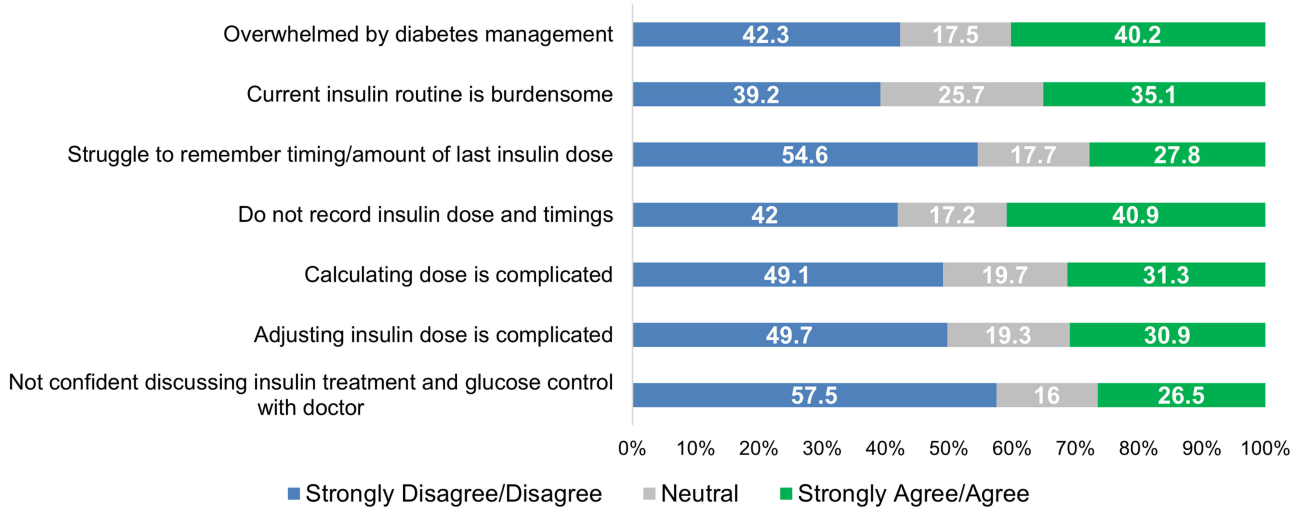


Figure 4 Difficulties people with diabetes reported with diabetes management. Participants were surveyed on what they perceived as the main difficulties associated with diabetes management.

https://doi.org/10.2147/PPA.S511332

surveyed as to how much they agreed with various difficulties associated with insulin management; 40.9% of PwD agreed or strongly agreed that they did not record their insulin dose and timings and 40.2% agreed or strongly agreed that they felt overwhelmed by diabetes management. PwD reported that they found their insulin routine burdensome (35.1%), calculating dose complicated (31.3%), adjusting insulin dose complicated (30.9%), struggled to remember timing/amount of last insulin dose (27.8%), and were not confident discussing insulin treatment and glucose control with doctor (26.5%).

Suboptimal insulin dosing is a challenge for many PwD, and barriers to achieving optimal dosing continue to exist. HCPs are integral in providing PwD guidance and resources to encourage proper self-management practices of the disease. To understand how to improve this coordinated effort between PwD and HCPs, PwD were surveyed as to whether they have had discussions about suboptimal insulin dosing with their HCPs in the past 30 days, and the extent of their comfort level with these discussions. Less than half of PwD (41.3%) reported having discussions with their HCPs about missing insulin doses, taking insulin doses that were too low, or taking insulin doses too early or late. More than half of participants with T1D (54.3%) reported they had these discussions with HCPs, whereas a smaller proportion of participants with T2D (36.7%) had these discussions. Interestingly, more than half (51.8%) of PwD reported they were either extremely comfortable or comfortable with having discussions with their HCPs about missing insulin doses, taking doses that were too low, or taking doses too early or late in the day or evening, and it was rare (6.1%) that PwD reported feeling extremely uncomfortable or a little uncomfortable (Table 2).

Solutions

When PwD were surveyed on solutions that might improve managing their insulin doses, the top 3 solutions PwD reported as very helpful were a device that automatically records glucose measurements (41.3%), having insulin and glucose data combined in one place (38.9%), and a device that automatically records insulin dosing and timing (35.6%) (Figure 5). Nearly half of participants (46.5%) in the United States reported a device that automatically records glucose measurements would be very helpful.

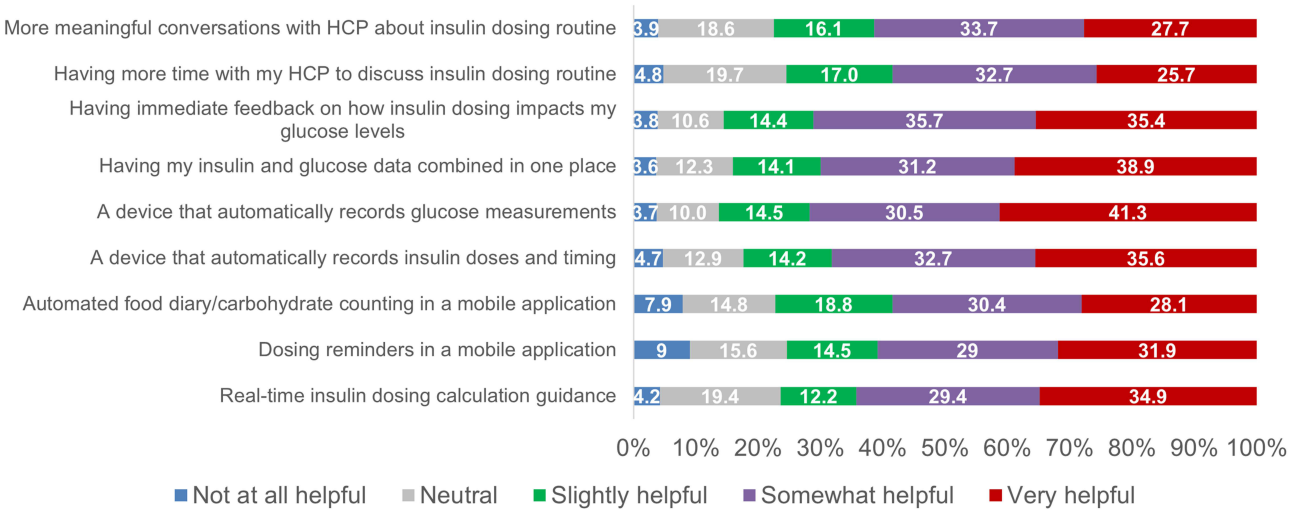


Figure 5 Solutions for managing insulin dosing.

Discussion

A wealth of literature exists detailing complications associated with T1D and T2D, and confirming the need to maintain targeted glycemic control to avoid diabetes-related complications.[4–8] Optimal insulin dosing is one key way to help maintain glycemic control. Our study examined a gap in the current literature, describing the intricacies of insulin treatment from the perspective of PwD with a focus on identifying and addressing the extent of missed, skipped, or mistimed insulin use. This study also aimed to identify and address reasons for suboptimal insulin use as well as solutions to the problem.

In 2018, Ellis et al published a review demonstrating that multiple barriers exist for HCPs and participants with T2D to achieve optimal insulin use in primary care, and suggested solutions such as more effective education for PwD, self-management support, and integrated insulin support systems.[15] In 2021, Robinson et al reported a systematic literature review on missed and mistimed insulin doses in PwD, and concluded that suboptimal insulin use was pervasive due to multiple factors including change in routine, social circumstances, and avoidance of hypoglycemia.[13] Higher HbA1c levels were shown to result from mistimed doses in participants with T1D,[16–22] and the Global Attitude of Patients and Physicians 2 study reported that clinical outcomes such as glycemic control were negatively impacted when participants with T2D missed approximately 3 to 4 basal insulin doses per month.[12,23,24]

In our study, 48.2% of basal dose users and 59.6% of bolus dose users, missed or skipped doses in the past 30 days; similar results were reported when basal and bolus users were asked about the number of mistimed doses. It is of interest to clarify whether triggers or barriers for PwD causing suboptimal dosing regimens were intentional or unintentional. When asked the main reason for missed or skipped basal and/or bolus doses, the most common answer reported in both cases was that participants forgot (basal: 34.1%; bolus: 25.2%), an unintentional barrier. The second most common reason for missed or skipped doses for basal and bolus users was being too busy/distracted, also an unintentional reason. The third main reason chosen by both basal and bolus insulin users for missed or skipped doses was that participants found it too complicated or burdensome.

Paradoxically, despite PwD reporting how prevalent their suboptimal insulin dosing regimens were and their associated reasons, PwD also reported that they felt mostly confident or extremely confident about managing insulin within the past 12 months. This level of confidence may reflect the fact that the largest proportion of participants (32.8%) had been diagnosed with diabetes for over 10 years, suggesting that many were experienced with treating their disease. Nearly half of the PwD in this study also reported using an insulin pen for over 2 years, further suggesting that the study population was not new to self-managing the disease using an analog insulin pen. When PwD were asked about their difficulties associated with diabetes management, the largest proportion (40.9%) strongly agreed or agreed that they were simply not recording their insulin dose and timings, a reason that is preventable. The second and third largest proportion of PwD reported more emotional reactions, such as feeling overwhelmed by diabetes management and that insulin treatment was burdensome (40.2% and 35.1%, respectively). The solutions PwD seemed to respond most favorably to were the use of devices that helped automatically measure and/or calculate data, with the 5 most popular potential solutions being devices that automatically record glucose, having data on insulin and glucose combined and located in one place, having a device that automatically records insulin doses and timing, having immediate feedback on how insulin dosing impacts glucose levels, and having real-time insulin dosing calculation guidance. The development of such devices, for example, insulin tracking devices and smart pens, is an ongoing area of research and has been reviewed extensively elsewhere.[25–27]

The majority of participants reported seeing a diabetologist, suggesting that PwD received specialized care and advice for self-managing their disease. The frequency of PwD meeting with a HCP may also be a strong indicator for success of treatment, and more than half of participants reported meeting with their HCP every 2 to 3 months, with 22.4% meeting once or more per month.

On average, PwD spend 3 hours per year with a HCP versus spending the remaining 8,757 hours of the year self-managing treatment of their diabetes.[28] Given this limited amount of time, HCPs should continue to strive to understand challenges and barriers associated with self-managing treatment, and enhance the tools available (such as training, educational resources, and digital aids) to help PwD foster healthy self-management of the disease. Helping PwD self-

manage may improve concordance with treatment and, hence, improve quality of life and health outcomes. Our data show that less than half of PwD (41.3%) reported having discussions with their HCPs about missing insulin doses, taking insulin doses that were too low, or taking insulin doses too early or late.

Strengths of this study included the international and relatively large number of PwD who reported on suboptimal insulin dosing from their perspective. Limitations of the study included the self-reported diabetes diagnosis confirmed via screening questions. Potential biases such as under-reporting due to recall or social bias may also have affected responses of PwD. In addition, as this study used survey panels to recruit participants and was an online survey, only participants with internet access were eligible to participate, hence the sample may not be representative of all adults who experienced suboptimal insulin dosing. This study was conducted from November 2021 to February 2022, during the Coronavirus Disease 2019 (COVID-19) pandemic.[29] However, insulin shortage was not reported during this time period, and we did not receive reports that the pandemic was interfering with dosing schedules. Although this study examined and described a large quantity of data, the authors were unable to evaluate and report on all possible subgroup analyses and their associated outcomes. Future studies should delve into subgroups associated with these data.

Conclusions

All survey studies are prone to some generalizability bias. The results described here do, however, strongly indicate that suboptimal insulin use is prevalent among PwD, with nearly half reporting missed or mistimed insulin doses in the past 30 days. Thus, there is a distinct need for support to help PwD self-manage insulin treatment in order to improve outcomes. In addition to increasing awareness of suboptimal insulin dosing practices, results from the survey may help PwD and HCPs address barriers to optimizing insulin dosing and seek potential solutions for managing insulin doses. The gaps identified in this study clearly point towards automation as a primary solution, both for data capture (such as glucose measurements and insulin dosing), and for medication dosing decision support.

Abbreviations

COVID-19, Coronavirus Disease 2019; HCP, healthcare professionals; PwD, people with diabetes; T1D, type 1 diabetes; T2D, type 2 diabetes.

Acknowledgments

The authors would like to thank the study respondents, and the investigators. In addition, the authors would like to thank Barbara Nambu, PhD, (Syneos Health) for writing assistance. The authors would also like to thank Rebecca Chanis, Nicola Barnes, Monica Hadi, Nashmel Sargalo, and Amy Clark from Evidera for their contribution to collecting data and developing survey materials and analyses.

Author Contributions

Conception of the work: RSN, ES, IB. Design of the work: RSN, EA. Analysis of data for the work: ES, IB. Interpretation of data for the work: RSN, ES, BL, JB, IB, EA, TB. Drafting of the manuscript: JB, IB. Critical revision of the manuscript for important intellectual content: RSN, ES, BL, IB, EA, TB. All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was sponsored by Eli Lilly and Co, Indianapolis, USA.

Disclosure

RSN, EA, JB, BL, and IB were employees and minor shareholders of Eli Lilly and Company during the time when the study was conducted and analyzed. ES is a paid external consultant for Eli Lilly and Company. TB served on advisory

panels of Novo Nordisk, Sanofi, Eli Lilly and Company, Boehringer Ingelheim, Medtronic, Abbott, Tandem, Dexcom, Roche, and Indigo Diabetes. TB received honoraria for participating on the speaker's bureaus of Eli Lilly and Company, Novo Nordisk, Medtronic, Abbott, Sanofi, Aventis, AstraZeneca, Dexcom, and Roche. TB's institution received research grant support from Abbott, Medtronic, Novo Nordisk, Sanofi, Novartis, Sandoz, Zealand Pharma, Slovenian Research Agency, the National Institutes of Health, and the European Union. TB was funded in part by the Slovenian Research Agency grant # P3-0343. The authors report no other conflicts of interest in this work.

References

1. World Health Organization. WHO fact sheets on palliative care. Geneva, Switzerland. 2021. Available from: https://www.who.int/health-topics/diabetes#tab=tab_1. Accessed May 30, 2023.
2. Saeedi P, Petersohn I, Salpea P, et al. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: results from the International Diabetes Federation Diabetes Atlas. *Diabet Res Clin Pract*. 2019;157:107843. doi:10.1016/j.diabres.2019.107843
3. International Diabetes Federation. IDF Diabetes Atlas. 10th edition. Brussels, Belgium. 2021. Available from: https://diabetesatlas.org/#:~:text=Diabetes%20around%20the%20world%20in%202021%3A,%2D%20and%20middle%2Dincome%20countries. Accessed May 30, 2023.
4. Phan T, Boutmy E, Coulombel N. A cross-sectional study on insulin treatments and glycemic control in type 2 diabetes in France, Italy, Germany, UK and Spain. *Value Health*. 2015;18(7):A334–A766. doi:10.1016/j.jval.2015.09.2053
5. Jude EB, Nixon M, O'Leary C, et al. Evaluating glycemic control in patients with type 2 diabetes suboptimally controlled on basal insulin: UK ATTAIN real-world study. *Diabetes Ther*. 2019;10(5):1847–1858. doi:10.1007/s13300-019-0667-6
6. Idris I, Peng X, He X, et al. The trend of high-dose insulin usage among patients with diabetes in the UK: a retrospective study. *Diabetes Ther*. 2018;9(6):2245–2257. doi:10.1007/s13300-018-0515-0
7. Beck RW, Bergenstal RM, Cheng P, et al. The relationships between time in range, hyperglycemia metrics, and HBA1c. *J Diabetes Sci Technol*. 2019;13(4):614–626. doi:10.1177/1932296818822496
8. Lu J, Ma X, Zhou J, et al. Association of time in range, as assessed by continuous glucose monitoring, with diabetic retinopathy in type 2 diabetes. *Diabetes Care*. 2018;41(11):2370–2376. doi:10.2337/dc18-1131
9. Khunti N, Khunti N, Khunti K. Adherence to type 2 diabetes management. *Br J Diabetes*. 2019;19(2):99–104. doi:10.15277/bjd.2019.223
10. Brunton S, Gough S, Hicks D, et al. A look into the future: improving diabetes care by 2015. *Curr Med Res Opin*. 2011;27(Suppl 3):65–72. doi:10.1185/03007995.2011.603300
11. Peyrot M, Barnett AH, Meneghini LF, et al. Insulin adherence behaviours and barriers in the multinational Global Attitudes of Patients and Physicians in Insulin Therapy study. *Diabet Med*. 2012;29(5):682–689. doi:10.1111/j.1464-5491.2012.03605.x
12. Brod M, Rana A, Barnett AH. Adherence patterns in patients with type 2 diabetes on basal insulin analogues: missed, mistimed and reduced doses. *Curr Med Res Opin*. 2012;29(12):1933–1946. doi:10.1185/03007995.2012.743458
13. Robinson S, Newson RS, Liao B, et al. Missed and mistimed insulin doses in people with diabetes: a systematic literature review. *Diabetes Technol Ther*. 2021;23(12):844–856. doi:10.1089/dia.2021.0164
14. Gregg EW, Hora I, Benoit SR. Resurgence in diabetes-related complications. *JAMA*. 2019;321(19):1867–1868. doi:10.1001/jama.2019.3471
15. Ellis K, Mulnier H, Forbes A. Perceptions of insulin use in type 2 diabetes in primary care: a thematic synthesis. *BMC Fam Pract*. 2018;19(1):70. doi:10.1186/s12875-018-0753-2
16. Smythe K, Saw M, Mak M, Wong VW. Carbohydrate knowledge, lifestyle and insulin: an observational study of their association with glycaemic control in adults with type 1 diabetes. *J Hum Nutr Diet*. 2018;31(5):597–602. doi:10.1111/jhn.12561
17. Datye KA, Boyle CT, Simmons J, et al. Timing of meal insulin and its relation to adherence to therapy in type 1 diabetes. *J Diabetes Sci Technol*. 2018;12(2):349. doi:10.1177/1932296817728525
18. McCarthy MM, Grey M. Type 1 diabetes self-management from emerging adulthood through older adulthood. *Diabetes Care*. 2018;41(8):1608–1614. doi:10.2337/dc17-2597
19. Olinder AL, Kernell A, Smide B. Missed bolus doses: devastating for metabolic control in CSII-treated adolescents with type 1 diabetes. *Pediatr Diabetes*. 2009;10(2):142–148. doi:10.1111/j.1399-5448.2008.00462.x
20. Pańkowska E, Skórka A, Szypowska A, et al. Memory of insulin pumps and their record as a source of information about insulin therapy in children and adolescents with type 1 diabetes. *Diabetes Technol Ther*. 2005;7(2):308–314. doi:10.1089/dia.2005.7.308
21. Campbell MS, Schatz DA, Chen V, et al. A contrast between children and adolescents with excellent and poor control: the T1D Exchange clinic registry experience. *Pediatr Diabetes*. 2014;15(2):110–117. doi:10.1111/pedi.12067
22. Simmons JH, Chen V, Miller KM, et al. Differences in the management of type 1 diabetes among adults under excellent control compared with those under poor control in the T1D Exchange Clinic Registry. *Diabetes Care*. 2013;36(11):3573–3577. doi:10.2337/dc12-2643
23. Ampudia-Blasco FJ, Galán M, Brod M. A cross-sectional survey among patients and prescribers on insulin dosing irregularities and impact of mild (self-treated) hypoglycemia episodes in Spanish patients with type 2 diabetes as compared to other European patients. *Endocrinol Nutr*. 2014;61(8):426–433. doi:10.1016/j.endonu.2014.03.008
24. Leiter LA, Boras D, Woo VC. Dosing irregularities and self-treated hypoglycemia in type 2 diabetes: results from the Canadian cohort of an international survey of patients and healthcare professionals. *Can J Diabetes*. 2014;38(1):38–44. doi:10.1016/j.jcjd.2013.08.270
25. Adolfsson P, Björnsson V, Hartvig NV, et al. Improved Glycemic Control Observed in Children with Type 1 Diabetes Following the Introduction of Smart Insulin Pens: a Real-World Study. *Diabetes Ther*. 2022;13(1):43–56. doi:10.1007/s13300-021-01177-w
26. Steenkamp D, Eby EL, Gulati N, et al. Adherence and Persistence to Insulin Therapy in People with Diabetes: impact of Connected Insulin Pen Delivery Ecosystem. *J Diabetes Sci Technol*. 2022;16(4):995–1002. doi:10.1177/1932296821997923
27. Backfish M, Kovalchick K, Albert R, et al. Dose Accuracy and Reliability of a Connected Insulin Pen System. *J Diabetes Sci Technol*. 2025. doi:10.1177/19322968241301760

28. Diabetes UK. Diabetes education and self-management. London, England. Available from: https://www.diabetes.org.uk/professionals/resources/shared-practice/diabetes-education#:~:text=On%20average%2C%20people%20with%20diabetes,year%20with%20a%20healthcare%20professional. Accessed Jan 6, 2023.
29. Giovanetti M, Branda F, Cella E, et al. Epidemic history and evolution of an emerging threat of international concern, the severe acute respiratory syndrome coronavirus 2. *J Med Virol*. 2023;95(8):e29012. doi:10.1002/jmv.29012