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Adherence to the Data Submission Protocol in a Diabetes Telehealth Service Pre and Post Deployment of an Adherence Optimization Module

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Abstract. Background: Telehealth services for chronic diseases are becoming more and more popular since they are expected to improve health outcomes and reduce costs. Especially for diabetes patients, life-long disease management is required. However, there are situations in a patient's life, when motivation to continue the participation in disease management programs is low and the dropout-risk is high. Objectives: We analysed if an adherence management module provided to healthcare professionals within a pre-existing diabetes telehealth service can improve the long-term adherence. Methods: The adherence to the agreed data submission protocol was determined prior and post implementation of the adherence management module. Results: Adherence to the agreed data submission protocol was higher after implementation of the adherence management module as compared to previous years. Conclusion: Adherence to the agreed data submission protocol can be improved by helping healthcare professionals to identify patients at risk of dropout. Further analyses are indicated to proof these results in a prospective study.

Keywords. Telehealth, adherence management, dropout prevention, diabetes management

1. Introduction

1.1. Telehealth services for diabetes management

Diabetes is a chronic disease which is related to severe loss of quality of life [1] and high costs [2]. Telehealth services for diabetes patients are expected to increase quality of life and reduce disease related costs. A large review from 2017 showed significant improvements of the health status due to telemedicine strategies [3].

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1.2. Adherence to telehealth services – state of the art

There have been several small-scale studies concerning dropouts from telehealth services for diabetes [4], psychological disorders [5-8], nutritional indications [9-13], insomnia [14], erectile dysfunction [15], and physical activity [16]. In a recent paper, Petersen et al. presented a method for dropout prediction from a digital platform designed to facilitate lifestyle changes for patients with chronic diseases [19]. Other groups presented gamification-based approaches, which were summarized in two recent papers by Asadzandi et al. [18] and Alsalman et al. [19]. These activities mainly focus on a) prediction or risk assessment of loss to adherence or dropouts or b) provide measures to help patients to keep adherent to diabetes therapy. However, little is known about measures to support telehealth nurses and other healthcare professionals working with diabetes telehealth systems in keeping their patients adherent.

1.3. DiabMemory - Telehealth service for diabetes patients

In Austria, the Disease Management Program "Health Dialog Diabetes Mellitus" (HDDM[2], Versicherungsanstalt für öffentlich Bedienstete, Eisenbahnen und Bergbau – BVAEB, Austria) has been running since 2010 [20]. The HDDM is supported by the Telehealth Service for diabetes patients (DiabMemory, AIT Austrian Institute of Technology GmbH, Vienna, Austria) [21,22]. Throughout the past years, approx. 500 patients at a time are monitored within HDDM. Patients are recruited during their stay at one of the BVAEB health resorts. Each patient is equipped with a smartphone app and a blood glucose meter with Bluetooth interface for automatic data acquisition. Patients are requested to follow a schedule for long-term self-monitoring of their blood glucose values:

- Insulin dependent patients should submit ≥ 3 glucose values each day
- Insulin independent patients should submit ≥ 3 glucose values on ≥ 3 days per week
- Optional: Insulin dependent and independent patients can submit additional data:
  - blood pressure and heart rate
  - physical activity, including type of activity, intensity, and duration
  - body weight
  - insulin doses
  - subjective wellbeing
  - free text messages / comments / questions

All these data are synchronized with the individual patient account at the central telehealth service. After login at the DiabMemory web-service, the responsible healthcare professional has access to the data. All relevant data of one single patient can be plotted in a patient overview which helps to get a quick impression of the current status of one specific patient over the past days (Fig. 1) or to get an overview over his 24h glucose profile (Fig. 2). For each patient, healthcare professionals are requested to set individual thresholds for the normal glucose level (see Fig. 1 and 2).

To provide an overview of all patients, tabular lists and filters are used to sort by different columns, such as patient name, date of birth, time of last data submission, etc. Healthcare providers who care for up to 100 and more diabetes patients can manage their patients well based on this patient list.

[2] https://www.gesundheit.gv.at/aktuelles/diabetes-telemedizin (last access: 2022-03-29)

Figure 1 – Screenshot of the evolution of glucose values over time of one single patient as provided by the telehealth service. The target range for fasting and pre-prandial glucose values is highlighted in green.

Each patient monitored in the service is recommended to be contacted at least once per week. Messages from healthcare professionals are sent to the patients over a specific, secure feedback service. Additionally, if required, healthcare professionals can contact their patients via telephone. Case managers from the telehealth service centre can also contact patients and healthcare professionals if they identify any issues.

With increasing number of patients registered to the HDDM, we found that tools other than the patient list were required to identify, which patients require additional actions. Therefore, by the beginning of 2021, a specific adherence management programme including a new module was implemented, with the intention to support healthcare professionals and case managers in identifying patients at risk of a dropout.

1.4. Objectives

We analysed if an adherence management programme including a specific adherence management module provided to healthcare professionals and case manager within a pre-existing diabetes telehealth service can improve the long-term adherence to the monitoring schedule of the HDDM.

2. Methods

An approval for conducting these analyses was available from the ethics committee of lower Austria (vote number *GS1-EK-4/534-2018*).

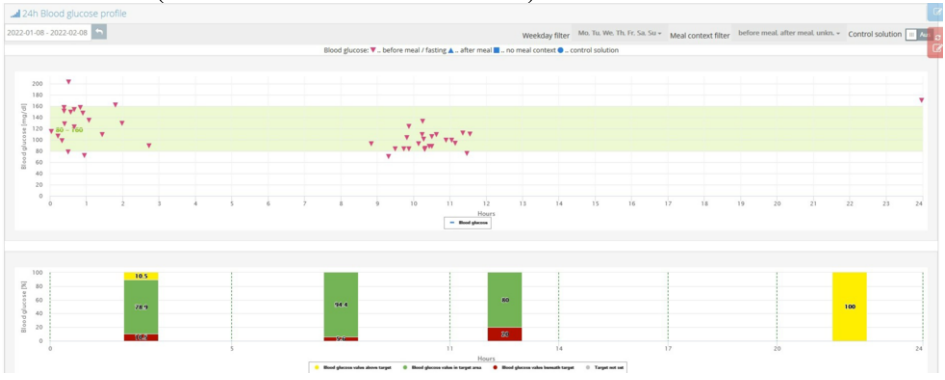

Figure 2 – Screenshot of the 24 h glucose profile of one single patient as provided by the telehealth service

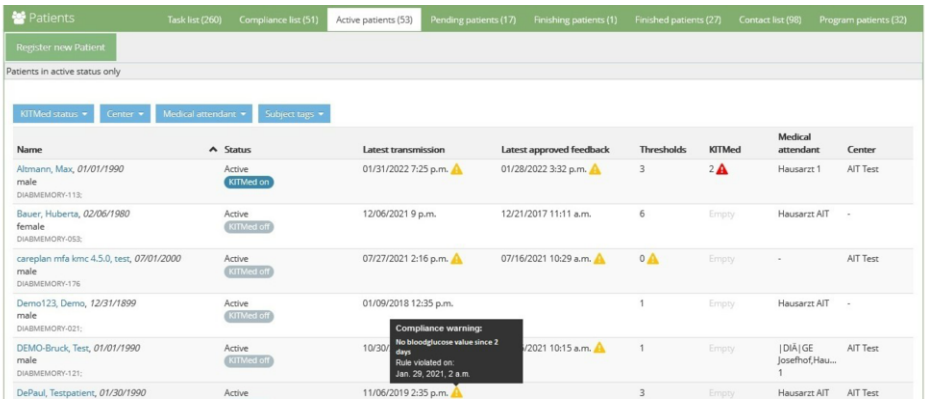

Figure 3 – Screenshot of the adherence module as shown to a telehealth service coordinator (screenshot taken from a test instance of the service – all names and data are fake)

2.1. Adherence Management Module

A rule-based adherence management module was added to the telehealth service by the beginning of 2021 which provides automatic checks for predefined rules. On a daily schedule, patients requiring special care are detected and flagged. The underlying rules address a) patients who submitted little data in the past days and b) patients that with missing inputs from the health care professional. The following rules were applied:

- No blood sugar value received in the preceding 21 days
- No feedback message sent to the patient since at least 14 days
- No thresholds specified for a patient registered since more than 8 days

A screenshot of the adherence module is provided in Fig. 3.

2.2. Adherence quantification and statistics

An export from the HDDM database was taken on 3rd February 2022. For each patient, the beginning and the end of the monitoring period was determined (i.e., time of first and time of last submission). Outliers defined as single measurements far off from all other measurements were not considered (might have derived from wrong date setting on the glucometer). Patients who submitted data on up to one single day only were excluded ("never-beginners"). Each patient was assigned to one out of three groups, based on their underlying monitoring schedule for blood glucose self-measurements (BGSM):

- insulin dependent (at least 3 BGSM per day, 7 days a week)
- insulin independent (at least 3 BGSM per day, at least 1 day a week)
- unknown insulin dependency status (at least 3 BGSM per day, at least 1 day a week)

Patients with unknown insulin dependency status were expected not to be insulin dependent. However, since their status was not documented, these patients were analysed separately. Adherence per week of insulin dependent patients was determined according to Equation 1.

$$adherence_{insulin\ dependent} = \frac{100}{7} * \begin{array}{l} (1 * \ n\ days\ with \geq 3\ \text{BGSM} + \\ \frac{2}{3} * \ n\ days\ with\ 2\ \text{BGSM} + \\ \frac{1}{3} * n\ days\ with\ \ 1\ \text{BGSM}) \end{array} \quad [\%] \quad (1)$$

For insulin independent patients, equation 2 was applied.

$$adherence_{insulin\ independent} = \begin{cases} 100 \ldots if\ \max(\text{BGSM}per\ day) \geq 3 \\ \frac{200}{3} \ldots if\ \max(\text{BGSM}per\ day) = 2 \\ \frac{100}{3} \ldots if\ \max(\text{BGSM}per\ day) = 1 \\ 0 \quad \ldots if\ no\ data\ were\ submitted \end{cases} [\%] \qquad (2)$$

For each patient, starting from the date of the first BGSM, for each calendar week, the number of days with at least 3 BGSM per day was calculated. These data were then analysed in two different ways, which are briefly described in the following.

2.2.1. Adherence over time

For each week since 2016, the mean adherence according to equations 1 and 2 among all patients active in that week, was calculated and plotted over time.

2.3. Adherence post vs. prior deployment of the adherence module

To quantify if in 2021 a significant change in the trend of adherence appeared, we selected those patients that were active on the first of January of each year from 2016 to 2021 and followed up their adherence over the respective year. Patients newly registered throughout that year were not considered. In this analysis, the adherence was expected to decrease over the year, since any dropout led to adherence=0 from the time of dropout on. However, our hypothesis was that in 2021, the loss of adherence was lower than in previous years.

For each week of the respective year, we calculated the adherence per patient according to equation 1 and 2. The loss of adherence in the second half of the year as compared to the first half of the year was calculated (equation 3). Data from 2021 were compared to data from previous years via box plots and the p-value was calculated by a two-tailed t-test.

$$\Delta Adherence = mean\big(adherence(Jul\ to\ Dec)\big) - mean\big(adherence(Jan\ to\ Jun)\big) \qquad (3)$$

3. Results

3.1. Patient overview

Table 1 provides an overview of the patient population.

Table 1 – Patient population. mn...mean, std...standard deviation

	insulin dependent	**insulin-independent**	**unknown**	**total**
Number of patients *(female)*	123(19)	490(74)	299(62)	912(912)
Age at registration [y] *mn ± std*	56±10	57±8	57±10	57±9
Monitoring period [d] *mn ± std (min-max)*	1458±814 (7-2565)	1546±884 (3-2580)	759±666 (2-2530)	1276±886 (2-2580)
Mean blood glucose in the first 3 months [mg/dl] *mn ± std*	151±33	130±24	136±30	135±29

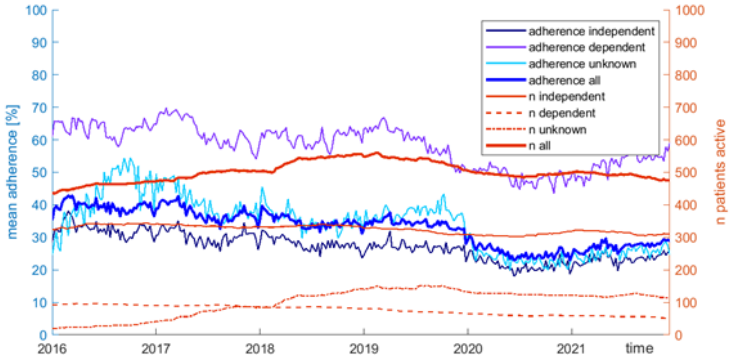

Figure 4 –Blue and purple: Ratio of adherent patients over time. Adherent patients were defined as patients with at least 7 days with at least 3 submissions for insulin dependent patients and with 1 day with at least 3 submissions per day for other patients. Red lines represent the number of active patients per group over time.

3.2. Adherence over time

Figure 4 shows the overall adherence to the submission protocol according to equation 1 and 2 over time from 2016 to 2021. Approximately 500 patients were active in that period, with a maximum in 2019. A decrease in the overall adherence in all groups (insulin dependent, insulin independent, unknown, all) in the years 2016 to 2020 can be seen. From the end of 2020 on, adherence increases again.

3.3. Adherence post vs. prior deployment of the adherence module

Figure 5 shows boxplots of the difference in adherence in July to December minus January to June in the years 2016 to 2020 (prior) as compared to 2021 (post deployment of the adherence management tool). Boxplots are plotted for insulin dependent, insulin independent, unknown and for all patients. For all groups, the decrease of adherence over the year was significantly lower in 2021 as compared to previous years.

4. Discussion

Telehealth services are expected to improve the adherence to therapy and lifestyle changes in various chronic diseases such as diabetes. To achieve this effect, patients need

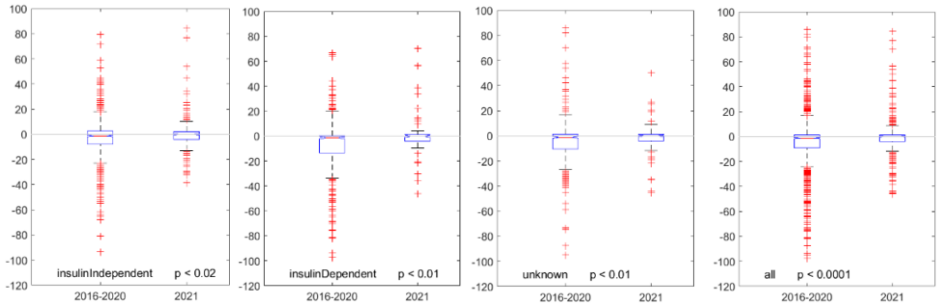

Figure 5 – Boxplots of the change of adherence according to equation 1 and 2 from first half to second half of the year of all patients active on the first of January of each year. Boxplots compare data from the years 2016-2020 to 2021 (pre and post deployment of the adherence management module).

to also be adherent to the defined schedule of the disease management program, i.e., to perform the BGSM according to the respective monitoring schedule. Over the past 12 years, many patients have been registered to the HDDM and many of those are still active today. However, some patients have also dropped out after days, weeks, months, or years. In some instances, it seemed like the reason for the dropout might have been detected and prevented, if the risk for the dropout had been identified in time and if appropriate measures had been taken (e.g., call the patient, ask for problems, provide help, etc.).

In 2020, we have started to implement various measures to improve adherence management in the HDDM. These measures were mostly designed for healthcare professionals, they should help to focus on those patients who needed special attention and, by that, they should improve those patients' adherence. One of these measures was to design, implement and deploy an adherence management module. The module was deployed in January 2021. In this paper, we demonstrated that adherence improved in 2021, as compared to previous years. However, looking at Figure 4, it seems like the change had already begun prior to implementing the module, i.e., by the end of 2020. Therefore, not only the module alone, but also other aspects of adherence management, including additional focus on the problem by the case management team, regular analysis of the adherence status, etc. might have had an influence on the overall adherence, too. We did not yet analyse the effect of each measure alone (have the number of feedbacks or unset thresholds changed?, etc.) Therefore, readers should not expect that simply deploying a module as described above will improve the adherence in similar systems if the module is not combined with other adherence optimization measures of the disease management program. Further analysis, preferably in a prospective setting, are required to separate the effect of specific parts of the whole adherence management program. Data concerning patients of unknown insulin dependency status are hard to interpret, since it is unclear whether they should measure and submit their glucose level on 1 or 7 days a week. Although, the portion of patients with unknown status is rather small, this also effects overall data. Therefore, insulin dependent and insulin independent data should be interpreted separately. In this study, we have shown an increase of patients' adherence to the agreed data submission protocol which is expected to be related to lifestyle changes and, in the end, improved clinical values such as HbA1c, as well. However, these effects cannot be shown with our data.

Up to now, within the adherence management module, patients at risk of dropout are listed based on a simple, rule-based algorithm (days since last submission, days since last feedback). Currently, we are developing machine learning based algorithms to better select the patients with the highest dropout risk. Such methods are expected to further improve the performance of the module. Although such approaches come with additional costs in terms of computational power, complexity, explainability, data protection, etc., we expect that in the future such data driven methods will further extend the potential of telehealth services.

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