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# Remission of Type 2 Diabetes from a Reduced Carbohydrate Diet with Digital Behavior Change Support: 15-month Case Study

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**ABSTRACT**

Type 2 diabetes is a global burden affecting over 400 million people across the world. The prevalence of type 2 diabetes is growing, driven by a sedentary lifestyle and unhealthy eating habits. In community settings, less than 1 in 1,000 people achieves type 2 diabetes remission. In the UK, adults eat 300% the recommended intake of added sugar in the diet. People diagnosed with type 2 diabetes are treated with diet and exercise before progressing to medications including metformin and insulin. Studies have highlighted the therapeutic benefits of carbohydrate restriction on health conditions including obesity, type 2 diabetes and epilepsy. The goal of this study is to assess the effects of a behavioral change intervention on primary markers of HbA1c and weight. This paper presents the case of a 72-year-old adult living in England diagnosed with type 2 diabetes in 2015 and referred to a digital behaviour change app (Low Carb Program) in 2018. The results of this study suggest lifestyle and behavior changes can be maintained with the assistance of a digital health app. This case study may lay groundwork for future research on technological and lifestyle approaches to manage type 2 diabetes.

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**Abbreviations**
**ADA:** American Diabetes Association
**HbA1c:** haemoglobin A1c
**NHS:** National Health Service
**NICE:** National Institute for Health and Care Excellence
**UKPDS:** UK Prospective Diabetes Study

## Introduction

Type 2 diabetes is a metabolic disease that affects over 415 million people around the world [1,2].

In the United Kingdom, the NHS spends over £25,000 a minute on diabetes and its complications [2]. Currently 90% of adults with type 2 diabetes are overweight or obese [3]. People with severe obesity are at greater risk of type 2 diabetes than obese people with a lower BMI [4].

Although considered to be a chronic and progressive disease, a growing evidence-base demonstrates type 2 diabetes can be placed into remission through weight loss and improved glycaemic control [3]. Reducing carbohydrates has been demonstrated 5 6 as the most evidence-based approach to achieving normoglycemia [4,5].

Digitally delivered programmes have been demonstrated to support behaviour change [6,7]. Although digital health apps use is widespread, adherence of digitally delivered interventions varies greatly and studies on long-term sustainability of approaches to type 2 diabetes remission, and remission management are limited [8,9]. In community settings, type 2 diabetes is rarely reversed [5,10]. Recent studies have also highlighted the impact of obesity and type 2 diabetes on COVID-19 risk factors [7,11].

## Case study (object)

This paper presents the case of B, a now 72-year-old male diagnosed with type 2 diabetes in 2015. B lives in the state of Hertfordshire, England, United Kingdom. He was diagnosed with type 2 diabetes at 67 years old. B is no longer clinically diagnosed with type 2 diabetes at the end of the study. B was referred to a digital intervention, Low Carb Program, by his NHS physician in June 2018. B followed the information presented in the application and reduced the amount of carbohydrates in his diet.

## Ethics

Members who are referred by their NHS healthcare professional team to access the program consent to the analyses of de-identified data. The local NHS R&D committee confirmed that this research would not require ethical approval.

## Method

B was referred to a digital app called Low Carb Program. Low Carb Program is a behavior change app that supports sustainable weight loss through providing tailored structured education for patients with type 2 diabetes, prediabetes, obesity, metabolic syndrome, polycystic ovarian syndrome (PCOS), non-alcoholic fatty liver disease (NAFLD) and general wellbeing. Education aids patients to reduce the sugar in the diet to 130g/carbs per day over a core 12-week implementation phase. Patients are provided support and resources including meal plans and recipes tailored to allergies, dietary preferences, culture and budget. Automated personalisation is achieved from the data collected on registration.

Education is personalised to disease profile (i.e. characteristics and descriptions of health and conditions), dietary preference, medications, health status and gender. The content and strategies used in the program build off prior research and theory. For example, evidence suggests that goal setting can act as an effective behaviour change strategy used to improve adherence to lifestyle intervention programs in obesity management programs [12]. Therefore, the program encourages participants to select a goal at the beginning of the program (e.g., to lose weight, reduce medication dependency, or make healthier choices for their whole family). Participants are also prompted to consider how their health would benefit from attaining their goal. Throughout the program, participants are periodically prompted to consider how close they are to attaining their goal. Recent findings suggest that program interventions that elevate the frequency of progress monitoring are likely to induce behaviour change [13].

Education modules are broken into lessons, action points, and supported with resources. Users can also ask questions on modules. Lessons are taught through videos, written content, or podcasts of varying lengths (approximately 5 to 12 minutes long). Users are provided a digital buddy, encouraged to find support from peers with similar goals in the community. Prior studies demonstrate that peer support may improve blood glucose control, peer-based support may be as effective for weight loss as coach-based support [14-16]. A daily-updated recipe library provides personalized recipe ideas for each meal of the day, and provides 7 day meal plans. The app provides users the ability to track their health (weight, HbA1c, blood glucose, food, mood, medication, ketones, cholesterol, blood pressure), track their nutrition with a food diary, connect the app with a wearable (Apple Health, Google Fit, Fitbit, Nokia, Garmin) and prompts users to check-in at regular intervals. The app is used within the NHS and has been demonstrated to facilitate weight loss and type 2 diabetes remission [17]. The platform provides native-language education and culturally relevant support for South Asians and is available on responsive web, iOS, Android, Apple Watch, Android watch, Alexa and VR (Oculus).

**Table 1: Weekly topics of the Low Carb Program**

| Week | Topic | Objective |
|---|---|---|
| 1 | Welcome to the Program | • Safety notes and alerts to medications that require health team's assistance<br>• Benefits of a reduced carbohydrate diet for people with prediabetes |
| 2 | Prediabetes and diet | • Factors that affect blood glucose levels<br>• Encouragement to engage with their healthcare providers |
| 3 | Controlling portion Sizes | • Visual methods of interpreting portion size |
| 4 | Real vs unprocessed foods | • Identifying and eliminating refined and processed food |
| 5 | Healthy and unhealthy fats | • Discussion of fat types and making appropriate choices depending on goals |
| 6 | Vegetables | • The carbohydrate content of vegetables and cooking methods |
| 7 | Fruit | • Reviewing the amount of sugar and starch in fruit and vegetables |
| 8 | Snacks and desserts | • Examining low-carb snack, dessert, and drink options |
| 9 | Drinks | • Alcohol and options for eating away from home |
| 10 | Eating out and takeaways | • Managing eating on the go and when travelling<br>• Making healthier takeaway and food choices |
| 11 | Practical ways to eat less carbohydrates | • Practical tips for reducing carbohydrate intake further<br>• Safety information – highlighting medications and co-morbidities that require healthcare professional assistance |
| 12 | Intermittent fasting | • Introducing the principles of reducing the eating window using the 16:8 model |

## Results

B engaged in the intervention 3 to 4 times a week averaging 20 minutes a week for the first 16 weeks of platform use. B used the web platform and respective iOS mobile application, completing 10 of the core 12 education modules. B posted 7 times in the community.

B used the app to keep a track of his food diary. B's average intake of carbohydrates as measured through the app in the first week of joining was 253g/carbs per day at baseline. At 16 weeks, the average intake of carbohydrates was 102g/carbs per day. At 15 months, B's average intake of carbohydrates is 109g/carbs per day. Most frequented food items in B's food diary were: cauliflower mash, omelettes, sardines, mackerel and poached eggs.

At 15 months, B engages an average of 9 minutes a week with the platform. At 15 months, B had reduced his HbA1c to below the threshold of type 2 diabetes diagnosis. B lost a total of 36.29kg and reduced HbA1c by 76mmol/mol. Average blood sugar levels have dropped by 2.2mmol/L.
B was confirmed to be in type 2 diabetes remission at 11 months.

B was interviewed as part of the case study report. B states: "In June 2018 I was told by the doctor that he was going to have to start moving me onto insulin injections as my metformin wasn't working. This frightened me and I said I'd be happy to do anything. I used to wake up during the night struggling with my breath, but the thought of injections was my main driver. I went back to my doctor in December and he was very surprised."

B reflects that his diet now contains significantly less cereal and rice. "The biggest thing was realising the overall sugar content of carbs, particularly cereal and rice, and how much they affect blood sugar. It seems a small thing to cut out, when you sit down and see what you're missing I don't regard it as very much. I was surprised it had such a huge effect."

B advises "keeping a record of weight and recording it at the same time each week helps you to see your progress, which is a motivation in itself". B confirms "meal planning and printing meal plans out for the week" help adherence to eating habits.

**Quantitative results**

| Metric | Before intervention | After intervention |
|---|---|---|
| Age | 70 | 72 |
| HbA1c | 112 mmol/mol | 36 mmol/mol |
| Weight | 109.32kg | 73.03kg |
| BMI | 36.5 | 24.4 |
| Diabetes medications | Metformin | - |
| Average blood glucose | 7.8mmol/L | 5.6mmol/L |

While there is a lack of clinical case studies on how low carbohydrate diets affect type 2 diabetes management, the results of the case report supports emerging and established evidence that lower carbohydrate diets can contribute to weight loss and improvements in blood glucose levels [18,19]. Weight and HbA1c were taken by B's physician, rather than self-reported.

However, B's food diary was self-reported. The sustained weight loss suggests that a lower carbohydrate approach may be a sustainable way of eating to manage metabolic health conditions such as type 2 diabetes. To maximize the effectiveness of the app's education, more research should be conducted to measure the effectiveness against other type 2 diabetes structured education programs.

The results of this case support wider studies that demonstrate digital apps can affect behavior change over the long-term [20-22]. Self-management of type 2 diabetes with digital health apps is a well investigated area of research and this case supports the health and engagement outcomes of other patients with type 2 diabetes engaged in the Low Carb Program [23]. Research should explore the features of the digital app ecosystem that are of most value to users. Whilst there are a lack of cases supporting long-term engagement in digital apps from older people, this study supports claims that older people may not be as hard-to-reach as previously understood [24-26].

For adults with type 2 diabetes, a low carbohydrate approach may help to lose weight and achieve normoglycemia. However, supporting long-term behavior change is not a one-fits-all approach and must meet the needs and concerns of the user. There are a number of factors affecting implementation of a lower carbohydrate diet, including local environment, budget and goals. Therefore individualized methods to support behavior change may be most optimal to engage and maintain long-term behavior change. A key promise of digital health technologies is its ability to support such personalization and this study supports future research into how the platform can be further extended beyond age, gender and ethnicity to maintain long-term engagement. The findings in this study may lay the groundwork for future research regarding long-term behaviour change support.

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