Improvement in body weight and glucose regulation with Season of Me

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Abstract

Lifestyle interventions aimed at reducing caloric intake and increasing physical activity have been generally successful at decreasing excessive body weight and improving glucose homeostasis. However, the impact of such interventions when coupled with personalized lifestyle insights that can be captured with the use of continuous glucose monitors (CGM) is less clear. We show the potential clinical benefit of a personalized program, Season of Me, that combines CGM with a mobile app linking each individual's glucose patterns to physical activity, sleep, and eating patterns in a cohort of 2,217 individuals, spanning a wide range of demographic, geographic, and socioeconomic characteristics. Participants ranged from self-reported healthy (non-diabetic) individuals to those with prediabetes and non-insulin-treated type 2 diabetes (T2D). Glucose patterns were captured over 28 consecutive days with CGM. Logged food intake, activities, body weight (BW), continuous glucose, and heart rate (HR) data were captured using a smartphone-based app. This mobile app continuously provided insights to participants, overlaying daily glucose patterns with activity and food intake —including macronutrient breakdown, glycemic index (GI), and glycemic load (GL); and personalized strategies to effectively manage the amount, composition, and timing of foods consumed and low-impact physical activities for the achievement of optimal glucose time-in-range (TIR). All groups of individuals — healthy, prediabetic, and T2D — experienced significant weight loss during the first month of the program. Strikingly, 100% of participants with T2D that continued Season of Me for an additional two months without CGM support, had a sustained weight loss trajectory, reaching a peak of 5.1% by 12 weeks. In addition, TIR improved in all participant groups: 74% of individuals with starting TIR (70-140 mg/dL) < 70% improved TIR by a median of 12.3%, and 72% of individuals with starting TIR (70-180 mg/dL) < 70% improved TIR by a median of 16.0%. All subgroups improved TIR from beginning to end of Season of Me, while individuals with T2D exhibited the largest percent improvement of all subgroups. Improvements in body weight and TIR were associated with improved dietary choices across all groups of participants. Overall, participants reduced daily caloric intake by 8.5%. The proportion of carbohydrates to calories was reduced in all groups by 4.4%, while the proportion of nutrient intake from protein, fiber, and healthy (monounsaturated and polyunsaturated) fats, as a ratio to calories, was increased by 13.5%, 23.2%, and 25.9%, respectively. These results suggest that the personalized lifestyle insights and recommendations offered by Season of Me lead to healthy lifestyle choices that result in clear health benefits such as lower body weight and improvement in glucose TIR. This technology merits consideration as an important tool to enhance current approaches to T2D prevention and treatment.

Background

37.3 million adults in the U.S. have diabetes, of which 95% have T2D [1]. Another 96 million have prediabetes. Twenty percent of those with T2D and 89% of those with prediabetes are unaware of their condition. The increasing prevalence of prediabetes and diabetes has been associated with many factors, including weight gain and physical inactivity. A sedentary lifestyle increases the risk for T2D by 20%

and each kilogram of weight gained increases the risk by 4.5% [2]. Three landmark studies (US, Finland, China) have shown that lifestyle intervention including dietary weight loss and physical activity can prevent diabetes progression in high-risk individuals by 51-58% [3, 4, 5] at 2.9 to 6 years, with continued protection of 27-43% for up to 20 years after the original intervention [5, 6, 7]. Two additional prospective trials in India and Japan showed similar protection at 3-4 years [8, 9]. These impressive results are tempered by difficulties with real-world implementation. The interventions in these studies were resource-intensive, implemented in highly-controlled settings, and often delivered by health care professionals, thereby limiting their real-world impact. New approaches to enhance the efficacy of lifestyle interventions to prevent and treat T2D are needed.

The explosion of new technologies that enable continuous glucose monitoring and food and activity tracking, as well as the widespread use of smartphones with 85% of US adults having a smartphone [10], provides a unique opportunity to leverage these technologies to significantly enhance efficacy and practicality of lifestyle interventions. Technology-enabled diabetes self-management approaches have gained traction as supplements or alternatives to traditional diabetes self-management models, with demonstrated improvement across a number of clinically relevant endpoints — including HbA1c, fasted glucose, circulating lipids, time-in-range, and hypertension [11]. To date, these technologies have not been integrated in a manner that increases user engagement and insight into their metabolic health in a meaningful way and traditional diabetes prevention methods are still the standard of care.

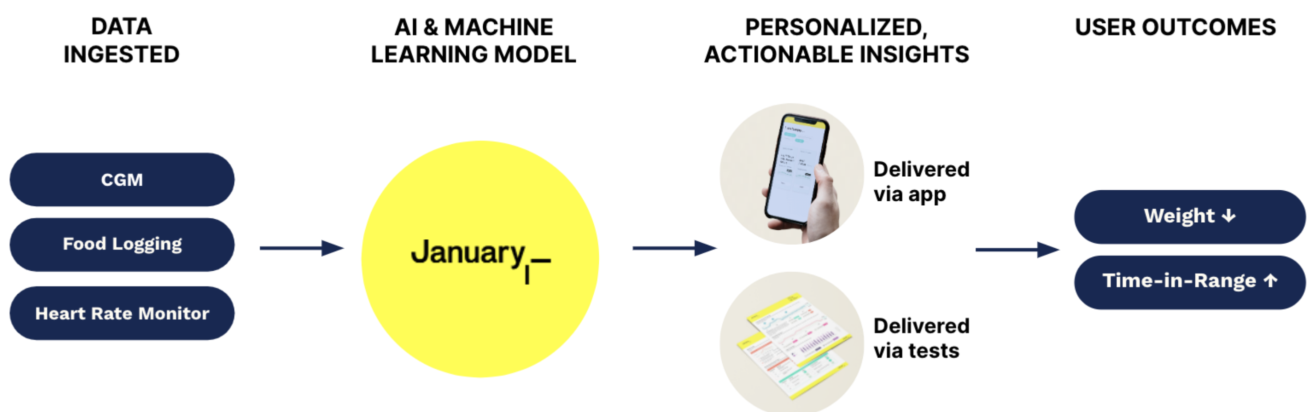
We propose that digital technologies can be used to collect and integrate consumer-generated health data, that can be presented in an accessible platform to participants in order to tailor education and individualize feedback that will offer substantial benefits over traditional lifestyle models by: 1) increasing self-efficacy and participant engagement, 2) personalizing lifestyle recommendations based on real data collected from the individual along with their personal preferences for food/activity, and 3) performing monitoring at home, thereby minimizing reliance on a healthcare facility and labor-intensive traditional diabetes prevention programs. In this way, technology can be conveniently harnessed to prevent and treat T2D and lower the associated health care burden.

The Season of Me Program For Personalized Metabolic Health Management

The Season of Me program is a comprehensive program designed to examine whether a 28-day use of CGM coupled with personalized lifestyle recommendations improves body weight and glucose homeostasis. The program was developed using the latest advances in medical sciences, technology, and artificial intelligence to seamlessly implement several clinically and scientifically validated strategies for the management of body weight and glucose regulation. The program consists of two phases: 1) an initial 28-day period that utilizes CGM and the mobile application to educate the participants about their individualized glucose patterns as well as eating and activity habits and teaches them how to improve these patterns; 2) a 2-month follow-up period during which participants implement and execute on the learnings without the use of CGM, relying only on personalized AI-driven recommendations. The January AI mobile application: 1) personalized total calories based on age, weight, height, sex, and physical activity, 2) encouraged participants to reduce their feeding period by 15-min at a regular cadence to achieve an ideal fasting state, 3) tracked and suggested fiber-rich foods to increase daily fiber consumption, 4) suggested a series of food and physical activity experiments to educate the participants on how glycemic rich foods elevate blood glucose levels and how physical activity can be used as a strategy to dampen excessive glycemic excursions, 5) identified foods that caused the largest increase in blood glucose and offered alternative lower-glycemic foods and lastly 6) provided educational content for stress management.

Briefly, the program utilizes an internally developed and proprietary mobile application that incorporates CGM and HR monitoring coupled with food and activity tracking and utilizes machine-learned algorithms for glucose predictions. Predictions are used to provide the participants with alternative food recommendations and physical activity suggestions to maintain blood glucose in a healthy range. The food recommendations utilize a large proprietary GI/GL food database and include alternative food choices for lower caloric density coupled, lower total carbohydrates, lower glycemic index (GI) values, lower saturated fats, higher dietary fiber, and lean protein. In addition, Season of Me provides personalized recommendations that minimize glycemic excursions in a given individual, and increase the percentage of time spent in the ideal glucose range (time-in-range; TIR). Two hours of predicted glucose responses are shown to the participant for each recommendation in order to motivate the participant to make those choices. The error in these predictions are 13.4 mg/dl RMSE over the two hours post-meal period. This error is on par with the best-published results, which do not report this high variance, post-meal period [12]. Notably, our two-hour, post-meal, glucose prediction error remains low, 14.8 mg/dl RMSE, even after participants have stopped using their glucose monitors, suggesting that the participant has learned their individual biology sufficiently well to predict their glucose response.

Figure 1: Data flowchart for Season of Me. Lifestyle tracking data recorded through the Season of Me app is used as input by January's proprietary AI to offer personalized, actionable insights to the user, resulting in improved metabolic health outcomes.



Criteria for Inclusion in Analysis

Downstream analysis of outcomes included only those individuals who had a sufficient quantity of CGM data capture, consistent food logging, and regular body weight tracking. Requirements for CGM data were at least 70% CGM coverage on at least half of the days at the beginning (days 3-7) and the end (last 14 days) of the 28 day period. Requirements for meal logging were active logging of all meals during the first 7 days, as well as the last 14 days. Requirements for body weight data tracking were at least one body weight measurement in the first 7 days and in the last 14 days.

User Outcomes

Endpoints associated with glucose metabolism and body weight were assessed to determine the benefits of Season of Me. Results are described in further detail below.

Study Results Demonstrate Improvements in TIR and Weight Loss

We enrolled 2217 participants: Glucose analyses included 1066 participants who were able to simultaneously observe their glucose patterns, food intake, and physical activity during personalized intervention schemes overlaid over the duration of the program. Weight analyses included 567 participants who met weight tracking criteria for inclusion per above. Over 27 million data points were captured across participant logs, heart rate, and continuously measured glucose data (Table 1).

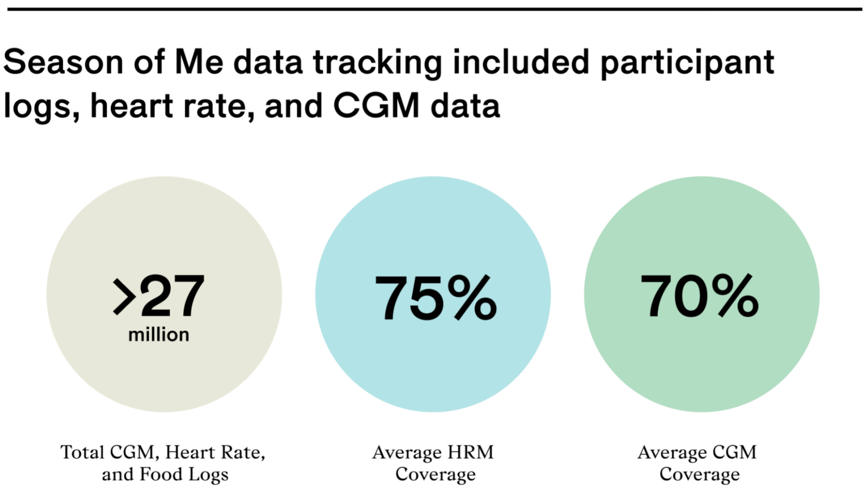


Table 1: Total number of data points, heart rate coverage, and CGM coverage.

Weight loss

To determine whether Season of Me promotes excess body-weight loss, we compared the final body weight measurement during the final two weeks of the program, with the first body weight measurement near the beginning of the program. All groups of individuals with quality CGM and body weight data significantly decreased their body weight over 28 days ($p < 0.0001$, Figure 2). Overall, 75.5% of the 567 participants with good CGM, body weight, and meal tracking data, as indicated in the methods section, improved their body weight, with an average decrease of 2.6 lbs (Table 2). Of interest, participants who continued the program for a total of three months, but were without the aid of CGM for months two-three, continued to lose excess body weight, reaching a nadir of 5.1%, or approximately 10.4 lbs in individuals with T2D, 2.3% or 5.2 lbs in individuals with prediabetes, and 1.5% or 2.6 lbs in healthy individuals (Table 3). Additionally, individuals with the highest starting body weight (250-300 lbs.) who continued logging weight through three months improved their weight by a mean of 6.8% (Figure 4).

Figure 2: All groups of individuals show a significant reduction in weight after participation in Season of Me, as indicated by a p-value < 0.0001 using a paired sample t-test across all groups ($p < 0.05$ *, 0.01 **, 0.001 *, 0.0001 ****).**

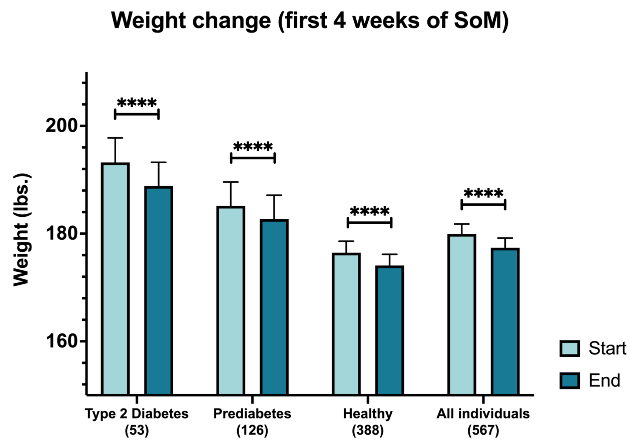


Figure 3: All groups of individuals who continued logging health data in the Season of Me app through 90 days maintained their weight loss, with groups of T2D and prediabetic individuals reaching their maximum average percent weight loss at week 12.

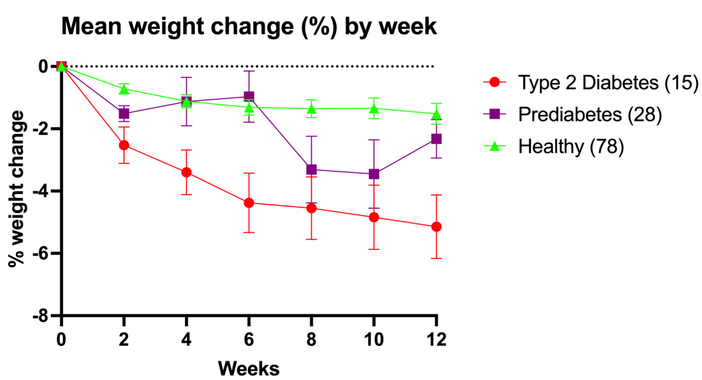
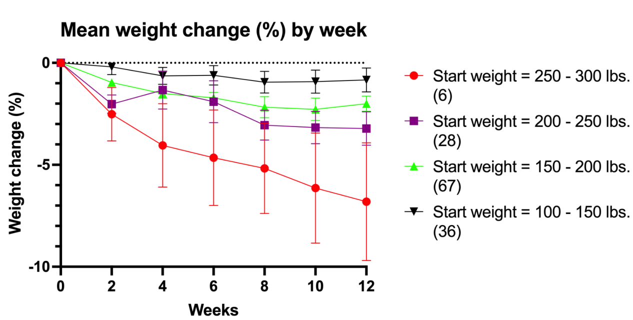


Figure 4: Individuals classified by starting weight who tracked their weight in the Season of Me app for 3 months showed continuous weight loss, as a percent (Fig. 4A), and in absolute pounds (Fig. 4B).

4A)



4B)

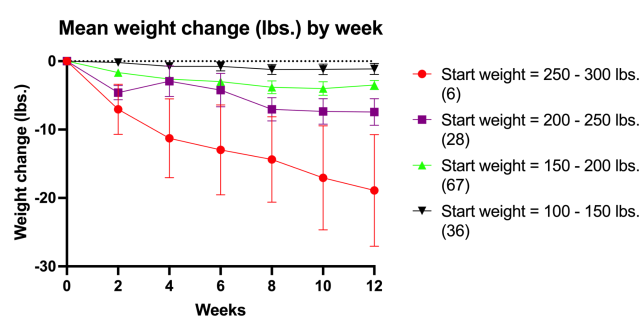


Table 2: All subgroups of individuals with good CGM, meal, and 1 month of weight tracking data, as indicated in the methods section, showed decreases in weight, with individuals with T2D showing the greatest weight loss and number of individuals who lost weight

Change in Weight | Season of Me (4 weeks)

Subgroup	Weight change (lbs.)	Weight change (%)	% individuals lost weight
All (567)	-2.6 lbs.	-1.4%	75.5%
Healthy (388)	-2.4 lbs.	-1.3%	74.0%
Prediabetes (126)	-2.5 lbs.	-1.4%	75.4%
Type 2 diabetes (53)	-4.4 lbs.	-2.2%	86.8%

Table 3: All subgroups of individuals with good CGM, meal, and 3 months of weight tracking data showed even greater decreases in weight through 3 months.

Change in Weight | Season of Me (12 weeks)

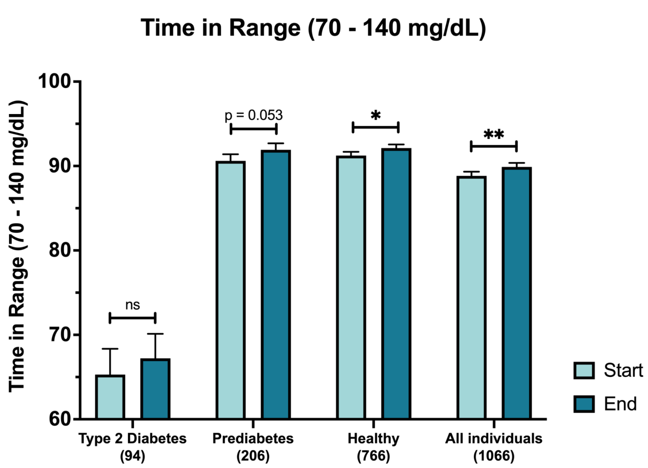
Subgroup	Weight change (lbs.)	Weight change (%)	% individuals lost weight
All (123)	-4.1 lbs.	-2.1%	72.4%
Healthy (79)	-2.6 lbs.	-1.5%	70.5%
Prediabetes (29)	-5.2 lbs.	-2.3%	65.5%
Type 2 diabetes (15)	-10.4 lbs.	-5.1%	100%

Glycemic control

In addition to weight loss, Season of Me significantly improved glucose homeostasis across all cohorts. Time-in-range (TIR) was calculated as the amount of time spent between the range of 70-140 mg/dL, or 70-180 mg/dL. TIR was compared between the beginning and end of Season of Me by calculating the TIR of days 3-7 with 70% CGM coverage, with the TIR of all days with 70% CGM coverage during the final two weeks of the program. Over 57% of all participants in the Season of Me improved their TIR by over 1% (Figures 5A and 5B). Participants experienced improved glucose stability, as shown by improvements in the coefficient of variance (%CV) (Figure 6). This is further reinforced by a notable decrease in hyperglycemic (Figures 7A, 7B, 7C) and hypoglycemic (Figures 8A, 8B) events. Moreover, participants who were above 180 mg/dL more than 10% of the time reduced their time-above-range (TAR) by a mean of 9.4%, with 74% of these individuals coming from the self-reported T2D subgroup. Individuals in all classes of glucose dysregulation (healthy, prediabetes, and T2D) improved their TIR, with those starting below the 70% target TIR exhibiting the largest improvements (Figures 9A, 9B), with a 15% mean improvement in TIR (70-140 mg/dL) and 20% mean improvement in TIR (70-180 mg/dL) (both p-values < 0.0001). This improvement in glucose dynamics was further seen through improved estimated HbA1C or the glucose management indicator (GMI), by a median of 0.95% in individuals with starting TIR under 70% and whose GMI was above 7% (the recommended maximum HbA1C level for individuals with T2D). A 1% improvement in HbA1c has been associated with reduced risk of cardiovascular events such as myocardial infarction, stroke, and heart failure, as well as overall mortality [13].

Figure 5: all groups of individuals improved their time-in-range between 70-140 mg/dL (Fig. 5A), and between 70-180 mg/dL (Fig. 5B).

5A)



5B)

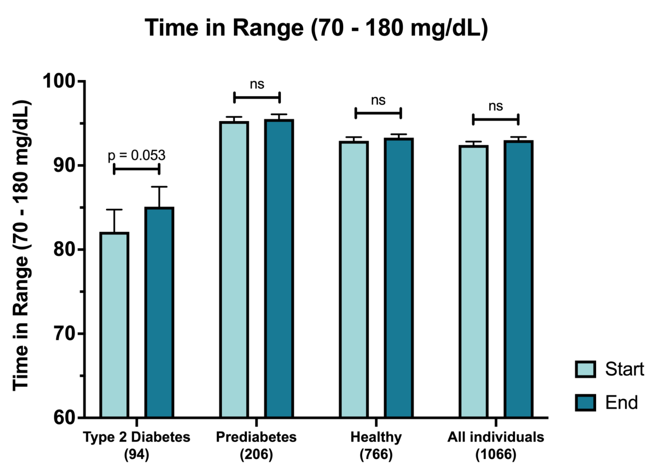


Figure 6: Glycemic variability, as measured by the coefficient of variation (100 * std. dev. glucose / mean glucose), improved across all groups of individuals, with p-values < 0.0001.groups.

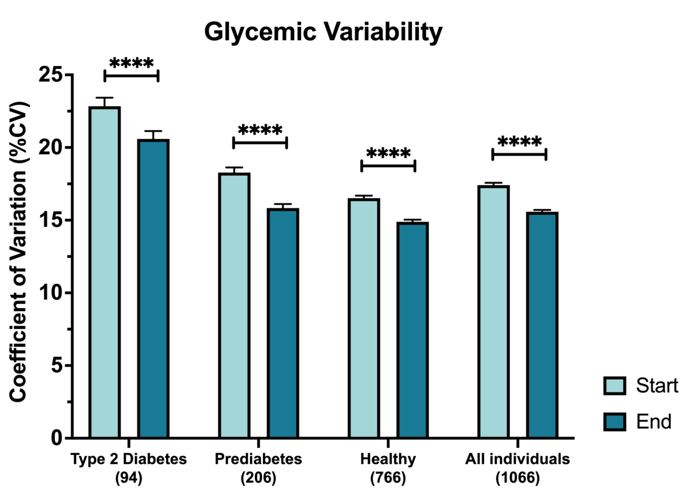
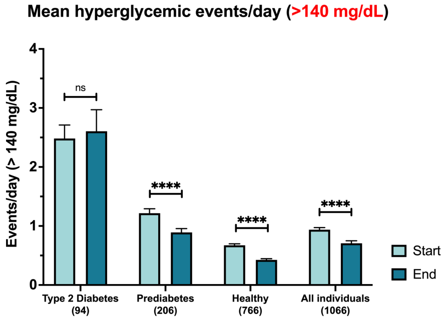
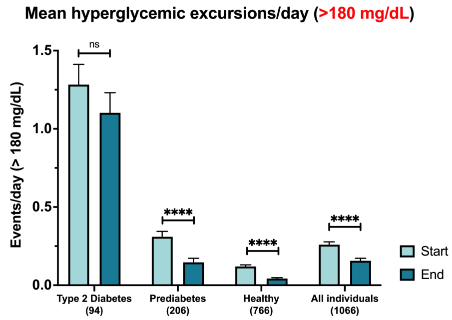


Figure 7: Individuals experienced less hyperglycemic events >140 mg/dL (Fig. 7A), >180 mg/dL (Fig. 7B), and > 250 mg/dL (Fig. 7C).

7A)



7B)



7C)

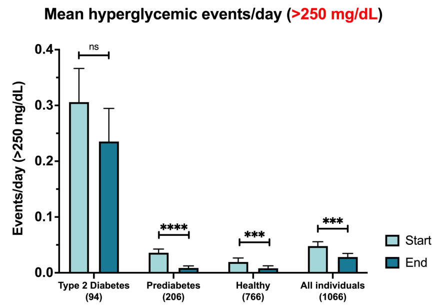
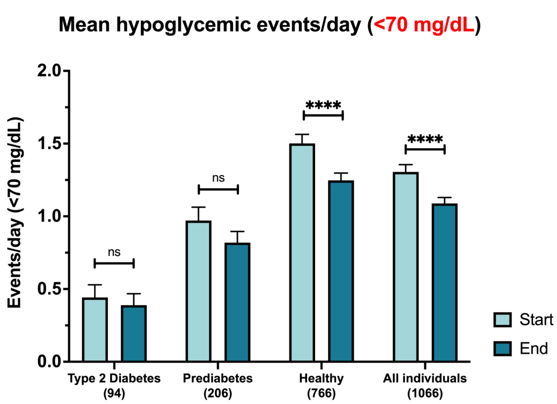


Figure 8: Individuals experience fewer hypoglycemic events <70 mg/dL (Fig. 8A), and <54 mg/dL (Fig. 8B).

8A)



8B)

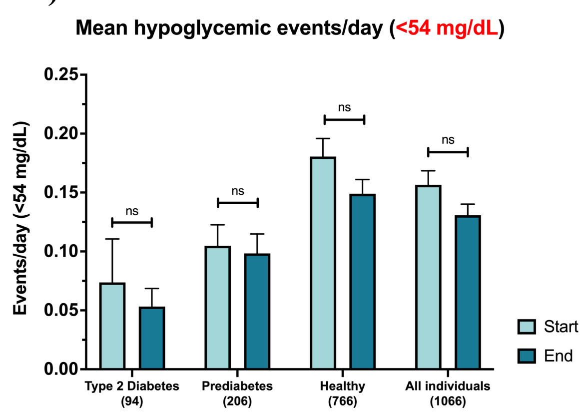
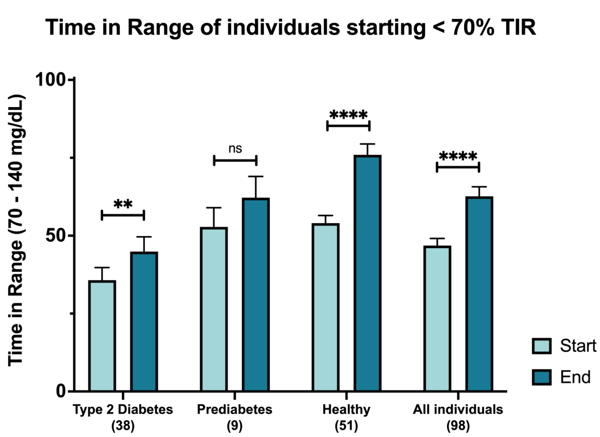
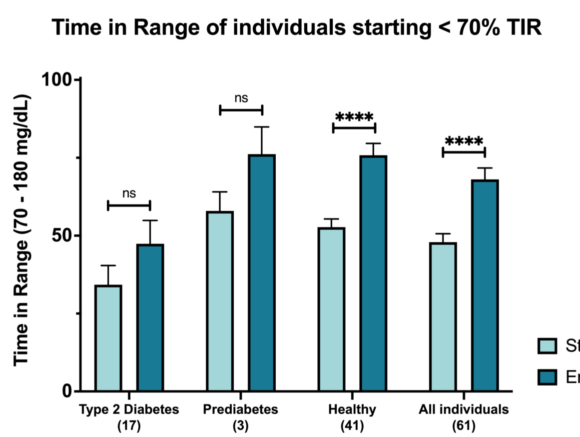


Figure 9: Improvement in glycemic control in individuals with baseline TIR < 70%: TIR defined as 70-140 (Fig 9A) and 70-180 mg/dL (Fig 9B).

9A)



9B)



Dietary habits

A key feature of Season of Me is personalized food insights and recommendations. Overall, participants with quality CGM, diet, and meal logging data across all cohorts reduced caloric intake by an average of 8.5% (Table 4). This reduction was associated with reduced reliance on carbohydrates and increased consumption of proteins and fiber, as a ratio to calories, by -4.4%, 13.5%, and 23.2% (Table 4). In the same group of 567 individuals, healthy fats (MUFAs + PUFAs) as a ratio to calories were increased by ~2.5x the change in the saturated fats to calorie ratio. Saturated fats as a ratio to calories increased only 2.6% and 2.0% in individuals with prediabetes and type-2 diabetes, while healthy fats (MUFAs + PUFAs) increased by 23.3% and 25.5%, respectively. In the same group of 567 individuals, 75.5% lost weight, with 86.8% of individuals with T2D losing weight (Table 2). Of all individuals that continued using the Season of Me through three months, 72.4% had lost weight after the third month, with 100% of individuals with T2D losing weight, for an average of 5.1% body-weight loss (Table 3).

Table 4: All subgroups of individuals showed a decrease in caloric intake and in the ratio of carbohydrates to calories from the beginning to the end of Season of Me program while increasing the ratio of protein, fiber, and healthy monounsaturated (MUFA) and polyunsaturated (PUFA) fats to caloric intake, indicating a shift in diet that favors glycemic stability.

% change in nutrient intake from beginning to end of Season of Me

Subgroup	Calories	Carbs/ Calories	Fiber/Calories	Protein/ Calories	(MUFA+PUFA)/ Calories	Saturated Fat/ Calories
All (567)	-8.5%	-4.4%	23.2%	13.5%	25.9%	10.6%
Healthy (388)	-7.7%	-4.3%	23.5%	13.7%	26.8%	14.5%
Prediabetes (126)	-7.4%	-4.6%	22.9%	13.3%	23.3%	2.6%
Type 2 diabetes (53)	-16.3%	-4.4%	22.2%	12.3%	25.4%	2.0%

Conclusions

Implementation of personalized lifestyle modifications utilizing a machine-learning-based platform that integrates logging of food intake and physical activity, a heart rate monitor, and a continuous glucose monitor is a new technology-based method that may increase the efficacy of the previously proven effect of lifestyle modification to prevent and treat T2D. The cornerstones of this intervention are weight loss and physical activity but prior recommendations have not been personalized according to variability in the biological response to foods and activity and/or personal preferences and habits, and have not synchronized data from different sources to better inform the user and motivate behavioral change. Results from the Season of Me program indicate that 28-day use of this novel method is an effective strategy to lose weight and improve glucose regulation in individuals with non-insulin-treated T2D, prediabetes, and healthy individuals. Furthermore, those that opted to continue the program for an additional two months continued their improved trajectory. Over 75% of all participants with sufficient CGM, meal, and body weight tracking data reduced their body weight, and individuals with the highest body weight who continued logging weight through three months improved their weight by a mean of 5.1%. Similarly, over 56% of all participants improved their TIR, and 72% of individuals with the lowest starting TIR (<70%) improved their TIR (70-180 mg/dL) by a median of 16.0%. By facilitating insights into the effects of lifestyle on glucose levels, it can be concluded that Season of Me effectively enabled individuals to make the necessary lifestyle adjustments at a personal level, resulting in improvements in metabolic health. Use of this integrative technology that empowers individuals to make informed lifestyle choices that promote weight loss and reduce hyperglycemia and glycemic variability holds the potential to revolutionize the approach to diabetes prevention and treatment.

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