Clinical outcomes from older adults in a digital diabetes prevention program

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Diabetes disproportionately affects older adults. The associated healthcare costs, morbidity, and mortality rates also increase with age. However, the majority of studies assessing clinical outcomes as part of the CDC's National Diabetes Prevention Program (DPP) utilized a cohort with an age range beginning at just 18. In this work, we report results from a retrospective subgroup analysis of participants in Lark's DPP aged 50-85 years at time of enrollment (n=360). We found average weight loss after approximately one year to be 4.3% (p-value < 0.001), demonstrating Lark's DPP to effectively engage and drive clinically significant health improvement for the older adult population.

1 Background

Diabetes affects 1 in 8 adults in the US and is a major driver of preventable healthcare costs, morbidity, and mortality. People with diabetes are at risk for comorbidities and complications such as hypertension, cardiovascular disease, nephropathy, peripheral neuropathy, and retinopathy. They accrue $237 billion in annual healthcare costs, and spend 2.3 times more on medical expenses than others. Diabetes cost is not limited to health expenses, with another ∼$90 billion annual cost from losses in productivity largely due to disability ($37.5 billion), presenteeism ($26.9 billion), and early mortality ($19.9 billion) [1, 2].

Diabetes is more common in older adults and the associated healthcare costs increase with age. While the condition only affects 4% of 18-44 year olds, it affects 25.5% of those aged 65 years and older [2], with the majority of cases developing in people over 45. Furthermore, 61% of the total medical expenditure attributed to diabetes is spent on the Medicare aged population, with an annual per capita diabetes related costs of $13,239, twice as high as those under 65 ($6,675) [1].

Type 2 diabetes (DM2), which accounts for 95% of all diabetes cases, is often preceded by prediabetes, a condition where one suffers from moderately elevated blood glucose due to insulin resistance. Like diabetes, prediabetes is more prevalent (33.9% in US) in adults and affects nearly half of the population aged 65 years and older [2]. 29% of people with prediabetes will develop diabetes within 3 years [3].

The progression from prediabetes to DM2 is generally attributed to modifiable risk factors and is preventable in many cases. The Centers for Disease Control and Prevention (CDC)'s national Diabetes Prevention Program (DPP) was designed to reduce risk of incident diabetes. Their landmark study, a year-long lifestyle change program, was focused on achieving 5-7 percent weight loss and 150 minutes of moderate activity per week. The program led to a 58% reduction in the risk of developing diabetes. In those aged 60 and older, the reduction was even greater (71%) [4].

Unfortunately, despite having 25% of adults eligible for DPPs express interest, only 2.4% ever participate [5]. Given a growing aging population, the unmet demand for DPPs will only increase. This exacerbates

Table 1: *Study participants initial BMI category by age*[*]

Age	Total	Overweight	Obese I	Obese II	Obese III
50-58	210	46	69	44	51
59-64	110	34	37	21	18
65-85	40	15	15	7	3

[*] Weight BMI categories are [25-30], [30-35], [35-40], $\geqslant 40$ respectively.

the need for scalable DPP providers who can effectively engage and deliver improved clinical outcomes for this age group. Digital DPPs have been touted as a strategy to reach a broad audience rapidly. However, there is concern that the older population may have unique challenges in adopting technology-based solutions [6]. Despite their high motivation for using digital solutions to improve health; older adults have reported barriers including fear of privacy breach, lack of trust, and not enough support and feedback [7, 8]. While studies on clinical effectiveness of DPPs have been focused on a wide age range of 18 years and older, the effect in the older population is of primary interest due to higher prevalence, risk, and associated costs [9, 10, 11, 12]. Therefore, this study complements the previous analysis of Lark's DPP outcomes in adults aged 18-76 [12] with the current study, which assess the clinical effectiveness of Lark's DPP in the subgroup of adults aged 50 years and older.

2   Design

This study was a retrospective, longitudinal cohort study among participants in Lark's DPP.

2.1   Cohort selection

We conducted a large retrospective, longitudinal cohort study of participants in Lark's DPP. All users qualified under CDC criteria to enroll in a DPP. This study is a subgroup analysis for participants aged 50 to 85 who had baseline BMI $\geqslant 25$, follow-up weight data within 10-14 months of program enrollment, and at least one in-app conversation after 10 months in the program. We then further limit the population to users with a reported weight measurement within their first two weeks in the program. This narrowed the cohort to 360 participants.

2.2   Intervention

Lark's DPP is a digital program that leverages artificial intelligence (AI) to deliver the CDC's PreventT2 curriculum on smartphones. Through this conversational text messaging program, Lark provides unlimited 24/7 real-time personalized counseling on nutrition, physical activity, stress management, and sleep coaching. During the on-boarding process, we collect both demographic and initial weight information from the user. All users were eligible to receive a free wireless scale, which seamlessly couples with the Lark platform. This allows us to continuously monitor a participant's progress regardless of their interaction with the app.

2.3   Analysis

The primary outcomes is weight loss at $\sim$1 year since joining the program. The initial weight is calculated as the first entered weight (manually or via connected device) and is limited to the first two weeks in the program in order to capture a full year of data. For final weight measurement, we allowed a broader window to account for gaps in weight recording at later times in the program. Participants needed at least one measurement between 10 and 14 months. The initial and final weights are then used to measure a user's percent weight loss. P-value calculations were done using a standard 2 sided t-test.

3   Results

Data from 360 participants in Lark's DPP were analyzed. The sample included 85 (23%) males and 275 females, with an average age of 57.8 ± 5.4, initial weight of 96.3 ± 20.5 kg and initial BMI of 34.8 ± 6.8. We calculated an average weight loss of 4.3% of total body weight for the whole population, and an average 4.4 kg weight lost. See table 1 for distribution of initial weights by age range.

Changes in BMI category can dramatically reduce health risks and healthcare expenditures [13, 14] Table 2 summarizes the changes in BMI category and weight loss by initial BMI for the users in this study. While it appears that people in the obese III category lose the most weight, a t-test comparing weight loss between that category and the Overweight category is only marginally significant (p = 0.07), indicating that initial weight category affects efficacy, but does not overwhelm other factors.

Of those participants with initial weight placing them in the obese III category, otherwise known as morbid obesity, 22% lost enough weight to move to a lower category of obesity. The overall BMI dropped from 34.8 to 33.2 and 99 people (28%) dropped at least one BMI category. Male and female users lost weight at

Table 2: *BMI shifts and weight loss over study period (1 year)**

Initial BMI	Final BMI					Total	Weight Loss (%)
	Normal	Overweight	Obese I	Obese II	Obese III		
Overweight	19	70	6	0	0	95	3.7
Obese I	4	29	84	4	0	121	3.8
Obese II	1	3	24	41	3	72	4.8
Obese III	0	0	3	16	53	72	5.7
Total	24	102	117	61	56		

* Weight BMI categories are [18.5-25) (normal), [25-30) (overweight), [30-35) (obese I), [35-40) (obese II) and $\geqslant 40$ (obese III).

similar rates without statistically significant difference between them.

4   Discussion

Based on proven engagement and clinical outcomes, Lark's DPP has obtained *Full Recognition* status from the CDC, the highest possible clinical status for a DPP. In this paper we described a study of 360 adults aged 50 to 85 in Lark's digital DPP. We calculated an average weight loss of 4.3% total body weight at approximately one year since joining the program. There was no statistically significant difference in weight loss between men and women or between age groups. The analysis also found that 22% of participants who were initially class III obese and 27.5% of participants overall dropped at least one BMI category. Previous research has associated higher BMI categories with increased risk for DM2, with class III obese and class II obese having DM2 odds ratios of 11.58 and 5.89, respectively [15]. We therefore conclude that Lark's DPP outcomes are clinically significant in decreasing the risk of incident diabetes and improving comorbid conditions, and consequently decrease costs related to chronic conditions.

A previous study found a 2.4% weight loss at ∼15 weeks in the program for 70 participants from a slightly younger population with an average age of 46.9 [12]. In order to compare both cohorts, we calculated the weight loss of this study's population at their 15 week mark. 322 users had a weight recorded between 14-16 weeks in the program, with an average weight loss of 3.0%. We believe the main contributors to the 25% improvement in weight loss outcomes may include product improvements over the last year and from Lark's capabilities to improve its AI models as it acquires more users and collects more data. This analysis demonstrates that Lark's digital AI DPP program can not only scale while retaining outcomes, but actually continues improving its medical outcomes as a result of scaling.

While weight loss in prediabetic people is crucial in order to prevent acquiring diabetes, Lark's DPP does not focus solely on weight loss outcomes. Rather, it is specifically designed to educate its users on general wellness, healthy eating habits, the importance of high quality sleep, and continuous activity. Therefore, we are planning on following up this article with a deeper analysis of primary and secondary outcomes and discuss further how those translate into health cost savings.

Older adults, especially the Medicare population (aged 65 and older), are affected by higher prevalence of prediabetes and diabetes. With age, these conditions become more costly and can significantly decrease productivity and quality of life. This study of 360 participants in Lark's DPP demonstrates that Lark is a scalable and effective solution for engaging and achieving long-term, clinically significant, weight loss in older adults.

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