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Original article

Participation of individuals with type 2 diabetes in a behavioural e-health lifestyle intervention in Denmark: A feasibility study

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ABSTRACT

Background: Behavioural lifestyle interventions can support type 2 diabetes (T2D) self-management; however, participation and adherence rates are often low. This feasibility study examined characteristics of individuals with T2D who were willing or unwilling to participate in, complete, and adhere to a personalised e-health behavioural lifestyle intervention in a general practitioner (GP) setting.

Method: Nurses at two Danish GP setting invited patients with T2D to participate in a one-year smartphone-based intervention. Patient characteristics were obtained from Danish health registers, GP records, and previously collected data. The personalized intervention included three face-to-face consultations (at baseline, 2 months, and 12 months) to set personal goals and measure weight, height, waist, and hip circumferences. Physical and mental health were assessed using the SF-12v1 survey. All other support and interactions occurred via app. Adherence to the app usage was evaluated by tracking logins, messages sent, and response times during the first and final three months of the intervention.

Results: Of the 63 eligible individuals with T2D, 20 (31.7 %) agreed to participate. Those who were willing to participate were predominantly men (75 %), younger (median age 57 years [IQR 52; 66] vs. 65 years [IQR: 57; 73]), had a longer duration of diabetes (6.6 years [2.9; 8.2] vs. 5.5 years [3.7; 7.0], higher fasting glucose levels (8.5 mmol/L [6.8; 10.4] vs. 7.9 mmol/L [7.1; 9.3]), and lower mental component scores (48.8 [38.5; 52.0] vs. 54.7 [47.3; 58.7]) compared to those unwilling. Of 20 individuals who were willing to participate, 13 (65 %) completed the intervention. After 2 months their mental component scores were 47.4 (40.6; 50.5), compared to 31.5 (31.5; 45.8) among those who dropped out. Additionally, completers demonstrated more consistent app usage, whereas app engagement among dropouts declined significantly over the first two months.

Conclusion: Willingness to participate in the behavioural intervention among individual with T2D was modest. Those willing to participate and completed the intervention were more often men, had better mental health, and showed higher app engagement than dropouts. These findings underscore the need for personalized strategies to improve participation and adherence in e-health lifestyle interventions.

Introduction

For individuals living with type 2 diabetes (T2D), behavioural lifestyle interventions, including dietary changes and physical activity (PA), can improve glycaemic control, reduce the risk of complications [1–5], and even induce remission [6,7]. Consequently, lifestyle modification is a recommended component of T2D treatment [8]. Despite the challenges associated with participating in such lifestyle interventions [9,

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10], many individuals with T2D prefer them over pharmacological treatment [11]. Therefore, it is crucial to identify and characterize both those who are willing to engage in lifestyle interventions and those who are not.

Non-adherence to T2D treatment is linked to poor disease control and a higher risk of complications [13]. Adherence to behavioural lifestyle interventions varies considerably among individuals with T2D [12]. A recent randomized trial found that eliminating copayments for cardiovascular disease (CVD) preventive medications in low-income adults at high risk did not lead to improve outcomes, suggesting that factors beyond financial barriers may influence both adherence to preventive interventions and baseline CVD risk [14]. Moreover, existing literature on adherence to lifestyle interventions rarely explores the characteristics of individuals unwilling to participate, particularly before they are invited to do so. A better characterization of those who eventually choose to participate, as well as those who do not, is crucial for clinicians aiming to anticipate treatment responses and tailor interventions accordingly.

Smartphone applications (apps) are widely used to support self-management in the treatment of T2D [15]. Their scalability, accessibility, low costs, and ease of use make them particularly well-suited for daily support of self-management efforts [16,17]. Several studies have shown short-term improvements in lifestyle behaviour among individuals with T2D who use e-health solutions [18,19]. However, there is still limited knowledge about the characteristics of individuals with T2D who choose to participate in these interventions, as well as their long-term adherence to app usage.

The company Liva Healthcare Aps (Copenhagen, Denmark) has developed an app-based approach to support behavioural lifestyle changes, focusing on setting personalized lifestyle goals, support, and digital health guidance. The app can aid persons who are overweight in sustainable lifestyle changes and weight loss [20]. We have collaborated non-profitably with the company to develop a self-management app--based solution that, with minimal support, aims to facilitate behavioural lifestyle changes through personalized goal setting, data tracking, and digital e-health coaching [21]. This app-based approach has been shown in a municipal setting to promote sustained weight loss [22]. However, it remains unclear what distinguishes individuals who are willing users versus unwilling to participate, and what characterize those who adhere to a personalized, app-based lifestyle intervention.

In Denmark, general practitioners (GPs) are responsible for diagnosing and managing uncomplicated cases of T2D [23]. Therefore, if an app-based solution proves feasible in a Danish GP setting, it could serve as a foundation for large-scale nationwide implementation. To explore this potential, we conducted a feasibility study in a small Danish GP setting to address the following research questions:

Q1: Which baseline clinical characteristics distinguish individuals recently diagnosed with T2D who are willing versus unwilling to participate in a new personalized, app-based behavioural lifestyle intervention?

Q_2: Which clinical characteristics differentiate individuals recently diagnosed with T2D who complete versus those who do not complete a new personalized, app-based behavioural lifestyle intervention?

Methods

Study set-up and patient characteristics

This feasibility study was nested within the 'Danish Centre for Strategic Research in Type 2 Diabetes' (DD2) cohort study, which has been enrolling individuals recently diagnosed with T2D since 2010 [24]. It was conducted as a feasibility assessment for the lifestyle intervention within 'The Specialist-Supervised Individualized Multifactorial Treatment of Newly Clinically Diagnosed Type 2 Diabetes in General Practice Study' (the IDA Study) [25].

Two GP clinics in Odense, Denmark, volunteered to participate. Between 2010 and February 2018, they enrolled individuals with newly diagnosed T2D into the DD2 cohort. From February to March 2018, individuals previously enrolled in DD2 at these clinics were informed about the feasibility study and invited to participate by their own GP nurse. The same nurse was responsible for excluding individuals who were already participating in other lifestyle interventions, did not own a smartphone, had a smartphone older than an iPhone 4S or Android version 4.4, or were not Danish speaking.

Individuals enrolled in the DD2 cohort at the participating GP clinics between 2011 and 2018 were eligible for inclusion in this study. To characterize these individuals prior to the intervention, we used the DD2 dataset, which was linked to the Danish healthcare registers [23,26,27] (Fig. 1A and Appendix 1). Comorbidity data were obtained from the National Patient Register using ICD-10 and 8 codes (Appendix 1), including records for prior hospitalizations for general comorbidities, macrovascular, and microvascular complications from the index date of January 1, 2018, and up to 10 years prior (Fig. 1A, orange bar). Basic demographic information, including marital status at the index date, was retrieved from the Central Person Register. The number of individual patient contacts with their GP in the year prior to the index date was extracted from the National Health Insurance Service Register (Fig. 1A, red bar). Medication data were obtained from the Danish National Health Service Prescription Database, covering prescriptions within 180 days prior to the index date (Appendix 1). Additionally, laboratory data on fasting blood glucose (FBG), C-peptide, C-reactive protein (CRP), and glutamic acid decarboxylase antibody (GAD65) were retrieved from blood samples collected at the time of DD2 enrolment.

Nor formal feasibility thresholds were defined prior to the study. Feasibility was evaluated retrospectively based on completion and adherence patterns.

The app-based intervention

Individuals who were willing to participate in the app-based intervention received an email from the study counsellor with a brief description of the intervention and instructions on how to download the app (Liva Healthcare, Copenhagen, Denmark) to their smartphones [21]. The app included both online and offline chat functions and supported for face-to-face video consultations. Within the app, the counsellor, patient, nurse, and GP could collaboratively set personalised lifestyle goals for Physical activity (PA), sleep, eating habits, meal frequency, and smoking cessation. The intervention timeline is illustrated in Fig. 1B Prior to the intervention, the counsellor and the participant met in-person for a one-hour session to set personalised lifestyle goals, conduct a brief clinical examination, and build a personal relationship. Two additional shorter in-person meetings, which also included same clinical examinations, were held- one after two months and another at the end of 12 months intervention period. All other interactions between the participant and the counsellor took place online via the app. The counsellor contacted participants once a week during the first three months and monthly during the following nine months. In addition, automated notifications were sent weekly to prompt users to log their progress towards personalised goals in the app. If no progress was reported, the counsellor initiated additional contact and, if necessary, adjusted the goals. In case of continued lack of progress or app engagement, participants were contacted by phone to provide motivation and help set new goals.

The personalized goal setting and counselling were designed to support self-management of lifestyle behavioural. Alongside the intervention, participants also received standard guideline-based care from their GP.

Adherence to app use

For all individuals willing to participate in the intervention, we retrieved app usage data from the server. Specifically, during the first

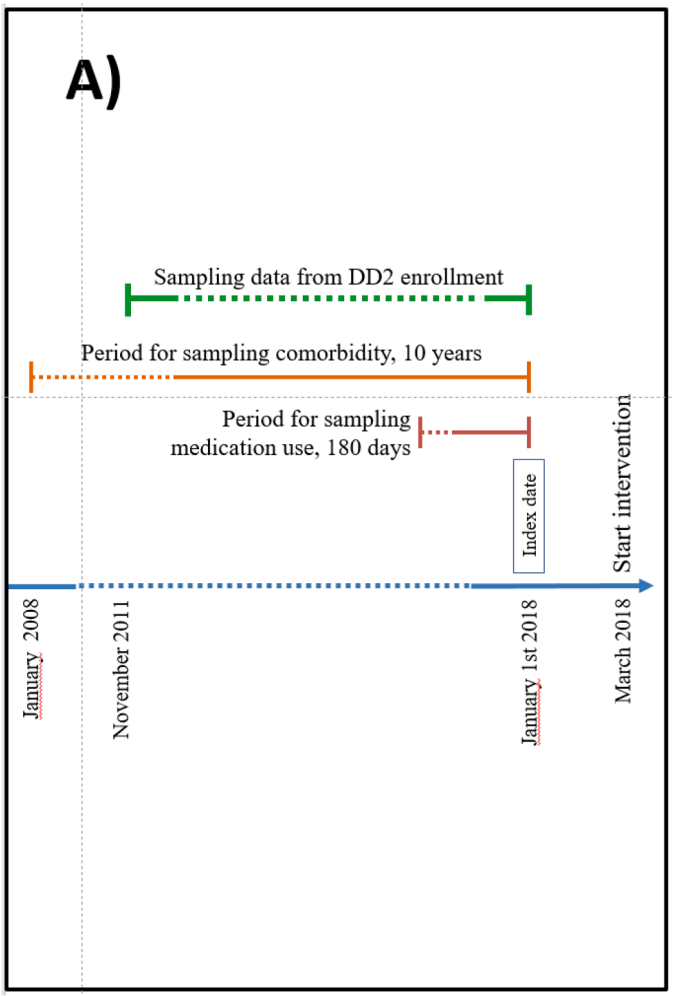

Fig. 1. A Timeframe for data collection prior to the index date (January 1st, 2018): hospitalization (10 years look back, orange bare), prescriptions (180 days, red bar), GP contacts (1-year, red bar), and DD2 enrolment (November 2011-February 2018, green bar). These data were used to characterize individuals willing and unwilling to participate in the intervention. B: Timeline of the 12-month digital lifestyle intervention (March 2018-March 2019). Face-to-face meetings with a health counsellor occurred at baseline, 2 months, and 12 months (blue arrows). Physical activity was measured via Liva app (light blue bars) and accelerometers (dark blue bars). App usage data were collected during the first and last three months (orange bars).

and last three months of the intervention, we collected information on the number of app logins, the number of messages sent, and the time (in days) it took to open new messages. For each participant, we calculated the average weekly number of messages sent to the counselor, which was used as a proxy for self-management within the intervention. Additionally, the time taken to open new messages from the counsellor and the number of weekly app logins during the final three months were used as proxies for adherence to app usage.

Variables to characterise participants

We retrieved the total number of daily steps from data recorded in the app, which was linked to the Apple Health or Android Health applications. Using these data, we calculated the average number of daily steps over three-month periods (Fig. 1B).

Self-perceived physical and mental health were assessed during the clinical consultation using the 12-item Short Form Survey, version 1 (SF-12v1). Individual responses were transformed into physical and mental component scores, each ranging from 0 to 100, with higher scores indicating better health functioning [28].

Height was measured using a stadiometer, weight with a digital scale, and waist and hip circumferences with a standard measuring tape.

HbA1c values were retrieved from the GP medical records if they had been measured within three months prior to the start of intervention, as well as during the two- and twelve- month follow-up consultations.

To obtain more detailed information on physical activity (PA), two triaxial accelerometers (AX3, Axivity, Newcastle, UK) [29] were attached to the skin- one on the thigh and one on the lower back- and worn continuously for 10 days following each clinical examination. Participants were instructed to wear the device without interruption.

Accelerometer data analysis was limited to waking hours, defined as 17 h per day from (6 a.m. to 11 pm.). During this period, the daily number of steps, time spent sitting and standing, and time spent on sedentary, light, moderate, and vigorous activity were calculated in minutes per day [30,31].

Missing data handling

For registry-based variables, no missing data were present, as the absence of a registered contact was defined as no contact. For app-based data, missingness was low across variables.

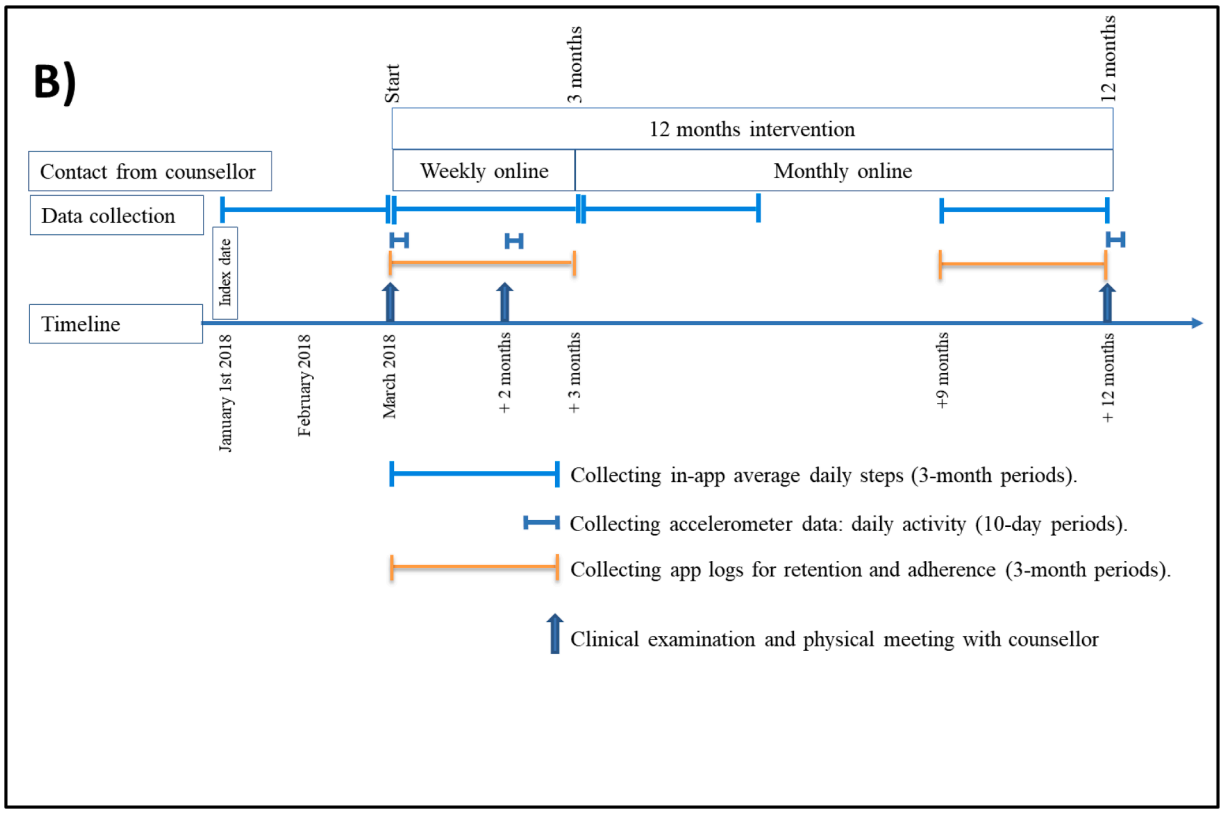

Fig. 1. (*continued*).

Data presentation

All data were managed in Excel and are presented as medians with the interquartile range (IQR) or percentage (%), unless otherwise specified. Due to the exploratory nature of this feasibility study, no formal statistical comparisons were conducted. Confidence intervals were omitted because the small sample size and substantial inter-individual variation would result in wide, overlapping intervals that offer limited additional insights.

Results

Characteristics of the persons willing and unwilling to participate in the app-based intervention

The participating GP clinics employed two and three medical doctors, respectively, making them representative of typical GP clinics in Denmark, where the average number of employed medical doctors per clinic is 2.3. From these two clinics, a total of 21 and 42 individuals with newly diagnosed T2D were enrolled in the DD2 cohort between November 2011 and January 2018. Consequently, 63 individuals were eligible for inclusion in this study. These 63 eligible individuals represented 75 % of all patients diagnosed with T2D in the two clinics during the same period.

Of the 63 eligible individuals, only 20 (31.7 %) were willing to participate in the intervention. The median time from enrolment in the DD2 to the point when the nurse invited the eligible individuals to participate in this study was similar between those who were willing and unwilling to participate: 2.1 years (1.8–5.1) vs. 2.5 years (1.4–5.1), respectively. Baseline characteristics of the eligible individuals at the time of DD2 enrollment are presented in Table 1. In brief, individuals who, on average two years later, were willing to participate in the intervention were younger at the time of DD2 enrolment, had a higher resting heart rate, and exhibited higher FBG level compared to those unwilling to participate. Interestingly, those who later chose to participate also had a lower mental component score than those who did not (Table 1).

Registry data retrieved at the index date (see Fig. 1), shortly before eligible patients were invited to participate in the intervention, revealed no major differences in comorbidity, physiological disorders, medication use, or frequency of GP consultations between those who were willing to participate and those unwilling (Table 2). However, a higher proportion of participants were married, compared to those who declined (Table 2).

Participation in the intervention and adherence to the app usage

Of the 20 individuals who initially agreed to participate, 7 dropped out with the first two months of the intervention. The remaining 13 people (65 %) completed the full 12-month intervention (Table 3). All dropouts occurred before the first follow-up face-to-face clinical examination at the 2 months mark. Notably, this group had substantially lower mental and physical component scores prior to the intervention compared to those who completed it (Table 3).

Of 13 individuals who completed the intervention, 11 maintained high adherence to app use, as measured by the average number of weekly logins and consistently short response times to messages from the counselor (Table 3). Furthermore, more than 90 % of these participants logged into the app at least once per week during both the first and last three months of the intervention. Remarkably, the average number of weekly messages sent by participants to the counselor declined over the course of intervention for all who completed it (Table 3).

Although all dropouts occurred within the first two months of the intervention, we were able to retrieve some stored app data for this group. This data revealed a lower average number of weekly messages sent to the counselor compared to those who completed the intervention (Table 3). Additionally, weekly app usage in this group was nearly zero (Table 3). Among those who dropped out, the counselor noted that a

Table 1
Baseline charactheristics of the eligible individuals by willingness to participate.

Variables	All persons ($n = 63$, (100 %))	Unwilling to participate ($n = 43$, (68 %))	Willing to participate ($n = 20$, (32 %))
Demographics			
Female	21 (33 %)	16 (37 %)	5 (25 %)
Age, *years*	63 (54; 72)	65 (57; 73)	57 (52; 66)
Anthropometry			
Height, *m.*	1.72 (1.66; 1.80)	1.70 (1.66; 173)	1.80 (1.70; 1.82)
Weight, *kg.*	85 (73; 102)	82 (72; 99)	89 (74; 111)
BMI, kg/m^2	29.4 (26.4; 33.1)	28.4 (26.5; 31.3)	30.0 (26; 34)
Hip/waist ratio (man)	1.03 (0.97; 1.06	1.04 (0.98; 1.07)	1.02 (0.95; 1.07)
Hip/waist ratio (woman)	0.90 (0.88; 0.96)	0.93 (0.89; 0.96)	0.89 (0.86; 0.93)
Weight at age 20 years old, *kg.*	68 (60; 78)	67 (59; 76)	73 (66; 79)
Weight highest ever, *kg.*	95 (84; 110)	95 (83; 106)	97 (84; 117)
Metabolic			
Fasting blood glucose, *mmol/mol*	7.9 (7.0; 9.7)	7.9 (7.1; 9.3)	8.5 (6.8; 10.4)
C-peptide, *pmol/mol*	1125 (844; 1467)	1158 (844; 1557)	947 (791; 1455)
GAD65, *n with* >20 *units*	1 (2 %)	1 (%)	0 (0 %)
Other			
Resting Heart Rate, *bpm*	70 (62; 80)	68 (60; 76)	72 (69; 84)
Mental component score	51.6 (41.8; 56.6)	54.7 (47.3; 58.7)	48.8 (38.5; 52.0)
Physical component score	52.3 (43.1; 55.5)	52.3 (37.3; 54.8)	54.2 (46.9; 57.2)
≥1 parent with known diabetes	31 (49 %)	20 (47 %)	11 (55 %)
Days pr. week with /≥30 min PA	4.0 (2.0; 7.0)	4,0 (1,0; 7,0)	3.5 (2.0; 5.8)

BMI: Body mass index; GAD: Glutamic acid decarboxylase antibody; PA: Physical activity.
Note:
• Values are given as median and interquartile range (IQR) or n (%).
• Baseline values at time of DD2 enrollment for all individuals eligible for the intervention, including those who were willing and those who were unwilling to participate. Complete data- on the 63 eligible persons- were retrieved due to mandatory data entry during DD2 enrollment.

Table 2
Characteristics at index date by willing to participate in app-based behavioural lifestyle intervention.

Variables	Unwilling to participate ($n = 43$)	Willing to participate ($n = 20$)
Demographics		
Age, *years*	65 (57.5; 73.6)	56.9 (53.2; 66.0)
Diabetes duration, *years*	5.5 (3.7; 7.0)	6.6 (2.9; 8.2)
Marital status		
Divorced	6 (14.0 %)	2 (10.0 %)
Married	22 (51.2 %)	17 (85 %)
Unmarried	8 (18.6 %)	1 (5.0 %)
Widowed	7 (16.3 %)	0 (0.0 %)
Glucose-lowering drug therapy		
Insulin-based therapy (and no metformin)	2 (4.7 %)	2 (10.0 %)
A Metformin	32 (74.4 %)	16 (80.0 %)
No glucose-lowering drug therapy	8 (18.6 %)	1 (5.0 %)
Other non-insulin-based therapy	1 (2.3 %)	1 (5.0 %)
Antihypertensive therapy		
1 antihypertensive drug types	15 (34.9 %)	8 (40.0 %)
2 antihypertensive drug types	8 (18.6 %)	4 (20.0 %)
3 or more antihypertensive drug types	6 (14.0 %)	2 (10.0 %)
No antihypertensive drug use	14 (32.6 %)	6 (30.0 %)
Antilipid therapy		
No antilipid therapy	9 (20.9 %)	3 (15.0 %)
Other antilipids	18 (41.9 %)	10 (50.0 %)
Simvastatin only	16 (37.2 %)	7 (35.0 %)
Antithrombotic therapy, *(yes)*	13 (30.2 %)	6 (30.0 %)
Anti psychiatric medications, *(yes)*	2 (4.7 %)	0 (0.0 %)
Charlson comorbidity index		
0	26 (60.5 %)	12 (60.0 %)
1–2	15 (34.9 %)	7 (35.0 %)
≥3	2 (4.7 %)	1 (5.0 %)
Ischemic heart disease, *(yes)*	1 (2.3 %)	2 (10.0 %)
Cerebrovascular disease, *(yes)*	2 (4.7 %)	0 (0.0 %)
Peripheral vascular disease, *(yes)*	0 (0.0 %)	0 (0.0 %)
Retinopathy, *(yes)*	2 (4.7 %)	1 (5.0 %)
Nephropathy, *(yes)*	0 (0.0 %)	0 (0.0 %)
Neuropathy, *(yes)*	6 (14.0 %)	2 (10.0 %)
Number of GP contacts in year 2017		
Consultations	8.0 (6.0; 11.0)	8.5 (4.5; 13.0)
Home visits	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
Consultations via phone or e-mail	6.0 (3.0; 9.0)	6.5 (4.0; 14.0)
Vaccination	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)
Other contacts	16.0 (12.0; 20.0)	11.0 (7.0; 19.5)

Note:
• Values are given as median and interquartile range (IQR) or n (%).
• Data for all eligible individuals were retrieved from the national registers due to register completeness.

lack of energy and/or time was frequently cited as a barrier to continued participation. Interestingly, the counsellor reported having established a stronger initial social relationship with participants who completed the intervention compared to those who dropped out.

For some participants, the counselor also noted a lack of technical skills (e.g., low e-health literacy), which led to frustration, annoyance, and ultimately reduced adherence to app use. According to the recruiting GP nurses, none of the willing participants initially presented with linguistic barriers. Nevertheless, one individual dropped out due to poor Danish language skills.

Characteristics before and after the app-based intervention

Among participants who completed the intervention, the physical component score increased compared to baseline (Table 3). This group also showed a modest increase in the daily time spent on moderate and vigorous PA, as well as in the average number of steps per day recorded by the app (Table 3). However, when using accelerometers to measure daily step counts, this finding was not consistently supported (Table 3).

Discussion

Main findings

We found that only one-third of individuals with a relatively short duration of T2D in this small Danish GP setting were willing to participate in this app-based behavioural lifestyle intervention. Notably, those who were most at-risk- both mentally and physically- two years prior to being invited were more likely to participate. Specifically, individuals who later agreed to participate had poorer mental health compared to those who declined. They also exhibited lower resting heart rates, suggesting reduced aerobic capacity, and were overall less metabolically regulated. These findings indicate that those who chose to participate were already experiencing significant mental and physical challenges. We speculate that the intervention may appeal to particularly the more vulnerable and fragile subgroup, especially, married men. However, dropout rates were notably higher among the most mentally fragile participants, suggesting that the intervention may not have provided sufficient support to sustain their motivation and engagement. We observed a higher proportion of men in the eligible group compared to the entire DD2 cohort [26]. Interestingly, eligible men showed a greater willingness to participate than women. Persons who completed this intervention did so despite a gradual and planned reduction over time in the number of contacts with the counsellor. We initially expected a

Table 3
Characteristics of individuals with T2D who were willing to participate in the intervention.

	Participants who completed intervention		Dropouts
Variables	Intervention baseline ($n = 13$)	After 12 months ($n = 13$)	Intervention baseline ($n = 7$)
Demographics			
Female	3 (23 %)		2 (28 %)
Anthropometry	$n = 13$	$n = 12$	$n = 7$
Height, *meters*	1.78 (1.68; 1.80)		1.81 (166; 186)
Weight, *kg*	91 (78; 111)	90 (77; 108)	80 (68; 123)
Body mass index (BMI), kg/m^2	30.0 (27.2; 34.2)	29.6 (27.3; 33.7)	28.9 (25.0; 38.1)
Hip/waist ratio (men and woman)*	1.00 (0.90; 1.05)	1.03 (0.97; 1.08)	1.03 (0.89 ;1.13)
Metabolic	$n = 13$	$n = 10$	$n = 7$
HbA1c, *mmol/mol*	54 (46; 60)	53 (46; 59)	55 (54; 64)
Physical and mental score	$n = 10$	$n = 11$	$n = 5$
Mental component score, SF-$12v_1$	52.0 (44.2; 55.5)	50.4 (36.5; 57.9)	34.1 (31.8; 45.8)
Physical component score, SF-$12v_1$	48.4 (39.5; 54.4)	51.4 (41.7; 52.7)	43.9 (31.5; 55.5)
Adherence to use of the smartphone application	$n = 13$	$n = 13$	
App activity, *No. of participants using the app every week***	11	11	NA
Messages from user to counsellor, *No. pr. Week***	1.2 (0.4; 1.5)	0.2 (0.0; 0.3)	NA
Time to opening of messages from counsellor, *days***	0.7 (0.1; 4.3)	0.8 (0.0; 8.4)	NA
Physical activity	$n = 11$	$n = 11$	$n = 4$
Average steps/day****	4868 (3492; 7251)	5447 (4224; 7195)	4799 (3326; 8030)
Average steps/day, *accelerometers*	5301 (3954; 6225)	4772 (3698; 6675)	2813 (2193; 4226)
Sedentary, *hours/day*	14.3 (14.1; 15.3)	14.4 (13.7; 15.1)	13.7 (13.2; 14.5)
Light activity, min/*day*.	141 (95; 171)	113 (104; 171)	167 (92: 215)
Moderate, min/*day*.	27 (20; 36)	32 (24; 40)	34 (24; 52)
Vigorous, min/*day*.	6 (2; 16)	8 (2; 12)	14 (3.6; 34)
Time spent sitting per day, *hours/day*	8.3 (6.4; 10.4)	9.4 (5.6; 10.8)	6.3 (5.0; 8.9)
Time spent standing per day, *hours/day*	3.8 (2.4; 4.3)	3.7 (2.7; 4.3)	4.4 (2.7; 5.7)

Note:
Data reflects participants' adherence to the one-year e-health intervention.
Values are presented as median with interquartile range (IQR) or as n (%).
NA= not available.
* Due to low number of women, the ratio is presented as the median for both sexes.
** Logged and stored during use of the smartphone app. Presented as averages from the first and last three months of the intervention.
*** Average steps/day was registered via the Liva app over a three-month period.

decreased use of the app over time, but many participants maintained high login in frequency and time to open massages. Overtime, the need to contact the counselor declined, suggesting improved self-management of their own lifestyle. Participants with a well-established personal relationship with the counsellor were more likely to complete the intervention and adhere to app compared to dropouts.

Comparison with other studies

Only one-third of our eligible participants were willing to participate. In a similar UK-based study, a web-based intervention was conducted in a larger GP setting where 968 people with T2D were invited to participate; in this setup, only 85 (8.8 %) accepted the participation [32]. Invitations in this UK study were sent via traditional post, whereas we utilized the local GP nurse, known to potential participants from previous visits, likely contributing to our higher recruitment rates [32].

Typically, men are less likely to engage in national health services and commercial lifestyle interventions [33–36]. However, in contrast to women, men tend to be more motivated by interventions that offer quantitative outcomes [37]. Our intervention included quantitative outcomes such as goal- setting for weight, step count, smoking, and diet. We speculate that the quantitative nature of our app-based intervention appealed more to men than women. Typically, app usage declines rapidly after initial engagement, and many apps are uninstalled shortly after download [38]. Contrary to our expectations of decreasing app usage over time, many participants maintained high login frequencies and quick response times to messages, indicating sustained adherence to app use. This was despite a planned reduction in the frequency of contracts from counsellors to participants.

Implications

Given these observations, we recommend carefully considering tailored app-based e-health behavioural lifestyle interventions for individuals exhibiting these characteristics to better support and engage this vulnerable group. However, the small sample size and the participation of only two highly motivated GP clinics limit the generalizability of our findings. These limitations should be acknowledged when interpreting the broader applicability of the intervention. Despite this, the study provides preliminary insights into the profiles of individuals who are more or less likely to engage with such interventions in a GP setting.

Our data do not allow us to determine the main drivers of sustained adherence and improved self-management. We can only speculate on these factors. However, long-term lifestyle changes are often supported by a strong patient-counselor relationship, which fosters motivation and adherence [20]. In this project, such a relationship was retrospectively confirmed by the counselor, suggesting that interpersonal support may have contributed to participant engagement. Future studies should explore whether similar relational dynamics can be cultivated in more diverse clinical settings and whether they contribute to sustained engagement across broader populations.

Strengths and limitations

One key strength of this feasibility study is its real-world setting, involving a well-characterized group of individuals recently diagnosed with T2D. This was made possible by integrating data from DD2, GP patient records, and various Danish health registers. Together, these sources provided comprehensive clinical and quality of life data for all eligible participants, collated two years prior to initiating the study.

The study design included two volunteer GP clinics that were highly motivated to participate. However, not all individuals with T2D from these clinics were included, introducing a selection bias that limits the generalizability of the findings. Furthermore, insights into participant adherence and motivation were based on retrospective recall from the counselor. A more structured approach to collecting qualitative data-such as conducting focus group interview- could have provided deeper and more reliable insights. Additionally, this feasibility study was initiated to evaluate proposed lifestyle intervention for inclusion in a larger intervention trial [25]. However, due to the low number of

individuals willing to participate, this setup was not incorporated into the main trial. In addition to willingness, other factors contributed to this decision, including restricted funding and the fact that recruitment for the larger trial progressed ahead of schedule.

Study adaptation and continuation

Liva healthcare A/S continued the development of the app independently. We shifted our focus to designing a new GP-centred logistical framework to support a different behavioural lifestyle intervention. This new setup includes the updated Liva app and a new GP-centred logistics model. It is currently being tested in a new study, for which participants recruitment is ongoing. The trial is registered at https://clinicaltrials.gov/ with the number NCT04880005.

Conclusion

The willingness to participate in this personalized, app-based behavioural lifestyle intervention was modest among individuals with recently diagnosed T2D in this small Danish GP setting. Two years prior to the intervention, those who later chose to participate were more often men, younger, more metabolically dysregulated, had a longer duration of diabetes, and reported poorer mental health compared to those who later declined participation. This suggests that the intervention may appeal particularly to a mentally and physically more vulnerable subgroup of individuals with T2D. However, the low overall willingness to participate indicates that the tested intervention is not feasible for the majority of individuals with T2D. This highlights the need for more personalized strategies to enhance both participation and adherence to e-health behavioural lifestyle interventions.

Before the intervention began, individuals who eventually dropped out exhibited poorer mental health, used the app less frequent, and did not establish a personal relationship with the counsellor, compared to those who completed this intervention. We speculate that the app-based format may not provide sufficient support for this more vulnerable group. In contrast, those who completed the intervention were more often men and demonstrated more consistent app usage throughout the study, suggesting that the setup was highly feasible for specific subgroup. Key factors contributing to this may include the app's emphasis on quantitative elements and the stronger personal connection that male participants appeared to have with the counsellor, compared to those who dropped out.

Ethics

The current feasibility study was considered part of the e-health intervention within the study titled IDA- trial, which was approved by the Ethics Committee of Southern Denmark (2012–004,883–23) and the Danish Data Protection Agency (2012–58–0018). Individuals who were willing to participate in the e-health intervention described in this study were subsequently enrolled in the IDA trial [38]. The IDA trial is nested within the Danish Center for Strategic Research in Type 2 Diabetes – the DD2 study cohort. The DD2 was approved by the Ethics Committee of Southern Denmark (S2010–00,082) and the Danish Data Protection Agency (2012–58–0035) [23].

Consent for publication

Not applicable.

Availability of data and materials

The datasets presented in this article are not fully publicly available because they contain data owned by The Danish Health Data Authority. These registers data cannot be made publicly available or shared by third parties due to Danish data protection legislation. All other parts of the datasets can be made available upon request to the corresponding author.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Microsoft Copilot to edit the manuscript. After using this tool, the authors revised and edited the content as needed and took full responsibility for the content of the publication.

CRediT authorship contribution statement

Fereshteh Baygi: Writing – original draft, Writing – review & editing, Visualization, Data curation. **Carl J. Brandt:** Conceptualization, Methodology. **Kathrine Kjær-Hansen:** Methodology, Investigation. **Anders Grøntved:** Conceptualization, Data curation. **Jan C. Brønd:** Data curation, Formal analysis. **Sia K. Nicolaisen:** Data curation. **Jacob V. Stidsen:** Data curation. **Reimar W. Thomsen:** Data curation. **Jens Søndergaard:** Methodology, Conceptualization. **Jens S. Nielsen:** Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author Carl J. Brandt is the founder of the Liva app used in this study and holds shares in the company. Jens Nielsen is currently employed as CEO by Sanofi Danmark A/S. However, Sanofi Danmark A/S had no role in the design, preparation, writing, or decision to publish this manuscript. The other authors declare that they have no competing interests.

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Appendix 1. Overview of the ATC codes used to determine medication use prior to the index date

	Code	Description
Glucose-lowering drug therapy		
Insulin-based therapy	A10A	Any antidiabetic therapy (see Appendix 2) was categorized hierarchically as follow: first use of metformin, if metformin was not prescribed, then use of insulin; if neither metformin nor insulin was prescribed, then use of other
Metformin	A10BA02	
No glucose-lowering drug therapy	–	

(*continued on next page*)

(*continued*)

	Code	Description
Other non-insulin-based therapy	A10	antidiabetic medications. Patients with no record of any of these treatments were considered naïve to antidiabetic medication.
Antihypertensive therapy	C02, C03, C07, C08, C09	The number of antihypertensive drugs was calculated by summing the presence of five specific ATC codes. Individuals with no prescriptions for any of these five codes within the defined time (180 days prior to the index date) were classified as Antihypertensive therapy naïve
Antilipid therapy		
No antilipid therapy	–	Anti-lipid therapy described in Appendix 2 is defined as any use of simvastatin, if not we looked for others. If both cases were negative persons were defined as anti-lipid therapy naïve.
Other antilipids	C10	
Simvastatin	C10AA01	
Antithrombotic therapy	B01	
Anti-psychiatric medications	N05	
Charlson comorbidity index	Based on data below and Appendix 2	Diabetes was removed from the calculation.
Ischemic heart disease	DI21-DI25	
Cerebrovascular disease	DI63-DI66, DI678-DI679, DI693-DI698, DI698, DI691	
Peripheral vascular disease	DI742-DI745, DI702	
Retinopathy	DH360, DE103, DE113, DE123, DE133, DE143, KCKC10, CKC15, KCKD65, KCKD05B, DH360K, DH360J	
Nephropathy	DE102, DE112, DE122, DE132, DE142, DI120, DI13, DN083, DN06, DO084, DR809, BJFD2, BJFD0, DZ992, DN17-DN19, KKAS00-KKAS20	
Neuropathy	DE104, DE114, DE124, DE134, DE144, DG590, DG632, DG603, DG609, DG618, DG619, DG620, DG621, DG622, DG628, DG629, DG630, DG631, DG632, DG634, DG635, DG636, DG638, DG990, DG561, DG562, DG563, DG568, DG569, DG570, DG572, DG573, DG574, DG576, DG578, DG579, DG580, DG587, DG588, DG589, DG598, DG900, DG560, DG575	

Appendix 2. Overview of the ICD-8 and ICD-10 codes used to define Charlson comorbidities

Disease	ICD8	ICD10
Myocardial infarction	410	I21; I22; I23
Congestive heart failure	427.09; 427.10; 427.11; 427.19; 428.99; 782.49	I50; I11.0; I13.0; I13.2
Peripheral vascular disease	440; 441; 442; 443; 444; 445	I70; I71; I72; I73; I74; I77
Cerebrovascular disease	430–438	I60-I69; G45; G46
Dementia	290.09–290.19; 293.09	F00-F03; F05.1; G30
Chronic pulmonary disease	490–493; 515–518	J40-J47; J60-J67; J68.4; J70.1; J70.3; J84.1; J92.0; J96.1; J98.2; J98.3
Connective tissue disease	712; 716; 734; 446; 135.99	M05; M06; M08; M09; M30; M31; M32; M33; M34; M35; M36; D86
Ulcer disease	530.91; 530.98; 531–534	K22.1; K25-K28
Mild liver disease	571; 573.01; 573.04	B18; K70.0-K70.3; K70.9; K71; K73; K74; K76.0
Hemiplegia	344	G81; G82
Moderate to severe renal disease	403; 404; 580–583; 584; 590.09; 593.19; 753.10–753.19; 792	I12; I13; N00-N05; N07; N11; N14; N17-N19; Q61
Any tumor	140–194	C00-C75
Leukemia	204–207	C91-C95
Lymphoma	200–203; 275.59	C81-C85; C88; C90; C96
Moderate to severe liver disease	070.00; 070.02; 070.04; 070.06; 070.08; 573.00; 456.00–456.09	B15.0; B16.0; B16.2; B19.0; K70.4; K72; K76.6; I85
Metastatic solid tumor	195–198; 199	C76-C80
AIDS	079.83	B21-B24

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