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A qualitative evaluation of a novel mHealth physical activity intervention with just-in-time prompts in people living with prediabetes and type 2 diabetes

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Abstract

Background Physical inactivity and prolonged sitting are major risk factors for prediabetes and type 2 diabetes (T2DM). Despite this, individuals with prediabetes and T2DM often face challenges in maintaining adequate physical activity. The ENERGISED trial aimed to address this by using a mobile health (mHealth) intervention combining wearable Fitbit devices, just-in-time context-sensitive text messages (JITAI), and telephone counselling, tailored to the needs of individuals with prediabetes and T2DM. This study explored participants' experiences with the intervention to inform future improvements and broader implementation.

Methods A qualitative study was conducted using semi-structured telephone interviews with 27 participants (20 with T2DM and 7 with prediabetes, aged 42–80 years) from the intervention arm of the ENERGISED trial. Interviews explored motivations for participating in the ENERGISED program and factors influencing subsequent adherence, as well as barriers and motivations and facilitators in physical behaviour changes, e.g., increased physical activity and reduced sedentary time. Data were analysed using abductive thematic analysis to identify key themes related to the intervention's components and participants' behaviour changes.

Results Two overarching themes were identified: (1) Motivations and facilitators to engaging with physical activity and the intervention, and (2) Barriers to engaging with physical activity and the intervention. Motivations were predominantly internal and health-driven, supported by intervention components, particularly the Fitbit device and telephone counselling, which enhanced self-monitoring, accountability, and adherence. Text messages showed mixed acceptability, with JITAI prompts to interrupt prolonged sitting perceived more positively than prompts to increase walking pace. The most prominent barriers were health-related limitations, adverse weather, work and time constraints, and technology-related difficulties.

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Conclusions The ENERGISED program demonstrated that mHealth tools, particularly wearables and personalised support, can aid self-reported lifestyle changes in prediabetes and T2DM management. Refining just-in-time text messages to better align with participant needs could further enhance outcomes. These findings are key for improving future mHealth interventions to increase physical activity and reduce sedentary behaviour in individuals with prediabetes and T2DM.

Keywords Digital health, Physical activity, Wearable devices, JITAI, Sedentary behaviour, Text messages, Phone counselling, Primary care, Fitbit, Wearables

Background

Physical inactivity and prolonged sedentary behaviour are significant risk factors for the development and progression of prediabetes and type 2 diabetes (T2DM) [1]. Evidence suggests that increasing physical activity (PA) and reducing sedentary time can improve glycaemic control, reduce the risk of diabetes complications, and enhance overall health outcomes [2–5]. However, despite the well-documented benefits, many individuals with prediabetes and T2DM struggle to maintain adequate levels of PA due to various barriers, including health complications, lack of motivation, and environmental factors [6, 7]. Poor motivation, insufficient social support, physical difficulties, and limited self-belief also affect physical inactivity [8]. To address these challenges and promote sustainable behaviour change, targeted interventions are essential to support individuals with prediabetes and T2DM in increasing PA and reducing sedentary behaviour.

Mobile health (mHealth) interventions have emerged as a promising approach to support behaviour change and increase PA among individuals with chronic conditions [9, 10]. These interventions leverage technology to provide personalised, just-in-time adaptive interventions (JITAI) that can help overcome barriers to PA by delivering timely and context-sensitive prompts. The ENERGISED trial exemplifies such an approach, aiming to increase PA and reduce sedentary behaviour in patients with prediabetes and T2DM [11]. It incorporates wearable devices (Fitbit Inspire) alongside just-in-time context-sensitive text messages and telephone counselling, all tailored to the individual's needs and circumstances [6].

Previous studies have highlighted the importance of participant-centred design in the development of mHealth interventions to ensure that they are both acceptable and effective [12].

In the ENERGISED trial, understanding factors that influence adherence—including perceived barriers and facilitators—is essential for refining the intervention and supporting its scale-up into routine care. A qualitative approach is particularly well-suited for this purpose, as it allows for an in-depth exploration of participants' experiences, motivations, and challenges, providing a comprehensive understanding of complex behavioural interventions [13–15] that quantitative methods might overlook.

The study aimed to explore participants' experiences of the ENERGISED intervention, focusing on the barriers and facilitators influencing its acceptability and adherence, as well as factors supporting improvements in physical behaviours (e.g., increased PA and reduced sedentary time).

Methods

Study design

This qualitative study, embedded in the ENERGISED trial's intervention arm, explored participants' experiences with the multicomponent mHealth programme, focusing on barriers and facilitators to acceptability, adherence, and perceived behaviour change. A qualitative approach was used to understand how participants engaged with the intervention's components—Fitbit activity trackers, just-in-time text messages, and telephone counselling—in daily life. The study followed the Consolidated Criteria for Reporting Qualitative Research (COREQ) to ensure methodological rigour and transparency.

The study's a priori focus on participants' experiences shaped the interview guide and analytic approach. To explore factors influencing acceptability and adherence, we used COM-B and the TDF to inform inquiry without predetermining themes, ensuring participants' perspectives remained central. The study aimed to understand how individuals with prediabetes and T2DM experienced the ENERGISED intervention, factors affecting adherence, and perceived changes in daily physical behaviours, to inform future optimisation and implementation of mHealth interventions targeting PA and sedentary behaviour.

The study has been approved by the Ethics Committee of the General University Hospital, Prague (No. 49/20). Informed consent was obtained from all individual participants included in the study.

Description of the ENERGISED intervention

A full description of the ENERGISED trial and detailed information on the intervention development have been published previously [6, 11]. Here we summarise the key features of the intervention relevant for interpreting the findings of this qualitative study.

The intervention was initiated in general practice. Adults with prediabetes or uncomplicated T2DM were recruited opportunistically during routine check-ups in collaborating general practices across the Czech Republic. After receiving brief PA advice and a Fitbit Inspire 2 tracker from their GP, all subsequent intervention components were delivered remotely by the study team.

At baseline, all participants were provided with brief advice on PA by their GP, accompanied by an educational leaflet, a recommendation to monitor their daily steps using the Fitbit, and a specific goal to progressively increase their baseline daily step count by 3000. Patients allocated to the intervention group additionally received a 12-month mHealth component comprising automated text messages and an initial six-month period of telephone counselling.

The telephone consultations were delivered by trained counsellors recruited from among university students and supervised by the research team. Drawing primarily on self-regulation theory, the counselling used behaviour change techniques such as goal setting, action planning, coping planning, review of goals, problem solving, feedback on behaviour, and social support [13]. The first call focused on negotiating an individualised step goal and identifying opportunities to integrate walking into daily routines. Together with the participant, the counsellor developed an action plan specifying when and how the additional walking could realistically be incorporated. Subsequent monthly calls at months 1 to 5, and an additional call after the six-month assessment, were used to review progress, discuss barriers, adjust goals where appropriate, and maintain motivation. The counsellors also assisted with technical issues related to Fitbit wear and synchronisation. Consultations typically lasted between 10 and 20 min.

Alongside the counselling, participants received six types of text messages that aimed to support their PA goals throughout the 12-month period. Two types were delivered as JITAI prompts, triggered by data from the Fitbit: prompts to increase walking pace when the participant had been walking for several minutes, and prompts to interrupt prolonged sitting when no steps had been recorded for 30 min. Three message types were sent on fixed days each week, including a Friday review of progress towards the weekly step goal, a Sunday summary with encouragement for the upcoming week, and short educational messages emphasising the importance of PA in (pre)diabetes management, which were delivered on Tuesdays. Finally, reminders of the individual action plans were sent at participant-selected times and days, aligned with the routines they had identified during the counselling calls. To avoid overburdening participants and to prevent the messages from following a predictable pattern, the individual message types were triggered randomly according to predefined probabilities. These probabilities were optimised so that most participants received approximately three to six messages per week, with rare weeks reaching up to ten messages.

Sampling and recruitment

All participants who completed 6 months of the ENERGISED intervention between 07/23 and 12/23 were approached for an interview. Purposive sampling ensured a diversity of participants by recruiting patients who completed the intervention across different seasons, which may affect PA. Out of 48 contacted participants, 30 initially agreed, but 3 later withdrew, resulting in a final sample of 27 participants. The sample's demographic characteristics included a range in age from 42 to 80 years (median age 66), with 15 women and 12 men, of whom 20 had type 2 diabetes and 7 prediabetes. This purposive sampling approach aligns with COREQ guidelines for enhancing data richness.

Interview methodology

Participants took part in semi-structured, individual telephone interviews lasting approximately 30 min, conducted by a research team member with qualitative research expertise (KJ). All participants and the interviewer shared the Czech language, ensuring comfort and ease of communication. Interviews were audio-recorded using a digital recorder, subsequently anonymised and transcribed using automated transcription software. The transcripts were left in their original form and manually checked for accuracy and completeness by the interviewer (KJ). To enable joint analysis within the research team, the verified Czech transcripts were translated into English using an AI-based translation tool. All translations were reviewed by the interviewer (KJ) for fidelity to the original meaning before being imported into NVivo12 (QSR International, Melbourne, Australia) for analysis.

COREQ guidelines were followed in developing the topic guide, which was shaped through discussions within the research team (KJ, CW, TV, JN, MU and TH). After the first few interviews, recordings were shared with the team to fine-tune the questions. The topic guide (Additional file 1) was informed by the Theoretical Domains Framework (TDF) [12] to ensure broad coverage of factors influencing acceptability of the program. We used the Capability, Opportunity and Motivation Model of Behaviour (COM-B model) [14] to support a comprehensive exploration of factors affecting adherence to the program, in line with COREQ recommendations to ensure conceptual depth in qualitative studies (Additional file 2). The interview questions primarily concerned opinions and experiences of the ENERGISED program as a whole [6], perceived barriers and factors

facilitating participation in the program and its adherence, but also participants' understanding of the role of PA, its benefits, and the consequences of inactivity in prediabetes/DM2. Before each interview, participants were reminded of their consent to be interviewed and for it to be recorded, assured of anonymity and confidentiality and reminded that they could end the interview at any time. After the interview, they were offered compensation for their time of 500 CZK (approx. 20 EUR).

Data analysis

The data were analysed using thematic analysis following established standards [15, 16]. An abductive analytic approach was used, integrating inductive, data-driven coding with deductive insights from behavioural frameworks. This iterative movement between data and theory allowed for a theoretically informed yet flexible exploration of participants' experiences, remaining open to unexpected themes within the complex behavioural intervention.

In line with COREQ recommendations on reflexivity, interview guides and analytic strategies were iteratively discussed within the research team to minimise researcher bias. Following Braun and Clarke's [15] methodological steps, two researchers (KJ, CW) read and re-read all transcripts to become familiar with the data. To maintain consistency and transparency, both researchers independently coded the same three interview transcripts, assigning descriptive labels to significant words, phrases, and sentences. They then met to compare and discuss their codes and jointly develop an initial coding framework. The preliminary framework was then applied independently to two additional interviews by each researcher, allowing for iterative refinement. Once consensus was reached on a final coding framework, it was used to systematically code the remaining transcripts. The researchers iteratively moved between coded data, emerging patterns, and relevant theory, consistent with abductive analysis. COREQ recommendations on data saturation were applied, confirming that no new themes emerged after a sufficient number of interviews.

Although we initially expected experiences to differ by step-count change, analysis showed substantial overlap. Many participants without large quantitative gains still reported perceived benefits, so groups were not analysed separately. Verbatim quotes illustrate general participant perspectives on specific topics rather than individual views.

Results

Two overarching themes were identified: motivations and facilitators to engaging with PA and the intervention (Table 1), particularly the text messages (Table 2), and barriers to engaging with PA and the intervention (Table 3). Within each theme, sub-themes were organised across two conceptual dimensions: internal vs. external factors and physical activity–related vs. intervention-related influences. This structure reflects both individual behavioural drivers and the role of intervention components in shaping engagement.

Motivations and facilitators to engaging with physical activity and the intervention

Internal facilitators - PA

Internal motivation to engage in PA was predominantly driven by a strong sense of responsibility for personal health, particularly in relation to diabetes management and prevention of disease progression. Many participants described increased awareness of health risks as a key reason for sustaining activity.

> *„I think it's good that at least the person realises again why he's doing it actually... that he's really doing it for his health, that he's not just doing it for the study, for the doctor.. he's doing it for himself." (male, 42, prediabetes)*

Self-efficacy, curiosity, and personal goals also supported engagement, with participants reporting satisfaction from monitoring their activity and striving to achieve self-set step targets. For several individuals, participation in the programme triggered a gradual shift towards habit formation, whereby PA became part of their routine rather than a study-related task.

> *„I have a need to be controlled by someone, but now that I'm used to it, I'll actually have control of myself." (male, 65, T2D)*

External facilitators - PA

External motivators for PA were comparatively limited. While recommendation by GP was often the initial reason for enrolment, ongoing engagement in PA was rarely sustained by social or environmental influences alone. Whilst occasionally mentioned, these factors had a secondary role compared with internal health-related motives.

> *„It was offered to me by my doctor… I said, why not?" (male, 58, T2D).*

The GP played an ongoing role throughout the study, systematically inviting patients for check-ups, monitoring, and examinations. Over time, this role also encompassed motivation. A notable and unexpected finding was additional program benefits, such as increased frequency of doctor visits.

Table 1 Summary of categories and themes – Motivations and facilitators to engaging with PA and the intervention

Category	Sub-category	Theme	Quotes
Internal factors - PA	own health	responsibility for themselves	*„Just take care of his body, take those walks, some exercise, a little bit also, of course, on the diet and here it's things just to get his body a little bit in order. "* (female, 51, T2D) *„Well, certainly that is what to improve your health, if not to maintain it. So the motivation was purely personal and maybe selfish. Thinking about myself, my health."* (female, 66, T2D) *„When you realize that you're doing it for yourself and that it's beneficial."* (male, 58, T2D)
		combined health motivations	*„I was also hoping to lose a little weight, which I guess I haven't managed to do so far. I needed to lose at least 10 kg, I'm still failing somehow, and that was probably the biggest motivation."* (female, 56, prediabetes)
		family burden	*„My mother, she actually had diabetes and such pretty, pretty high, it fluctuated etc. so the doctor said I'll have it too, but it's up to me then."* (male, 66, T2D)
	self-motivation	curiosity	*„If I'm going to have the program and I'm going to see the graphs and that. so it's just nice to be able to look back and compare, when I was efficient and stuff and how many miles I walked, and just that. that's what I was interested in."* (female, 66, T2D)
		self-testing	*„I took it quite honestly. I didn't take it as we did for the reason that somebody convinced me to do it, but I wanted to test myself to see if that increased activity or something would lead to that."* (male, 66, prediabetes)
External factors - PA	GP	why not to try?	*„I was just offered this by my lady doctor in the district, so I'm like, why did I accept? I was like, why not? I've never done anything like this in my life, why not try it?"* (female, 55, T2D) *„I went to see my business doctor and she offered it to me, so I wanted to comply, I was a bit curious too, so I said yes."* (male, 54, T2D)
Internal factors - Intervention		habit	*„I wish I was over it, but now maybe over the winter it's okay, you get used to it, so I imagine I'll have it all the time. Well, we'll see."* (female, 69, PD) *„I'll tell you this, I think it's so ingrained in me. what do you call it. responsibility for myself. that I wouldn't need it* (the program – note)*."* (female, 56, PD)
		lifestyle changes growing sense of control	*„Walking up the stairs, down the stairs or something like that. But outside I've got my bike, I'm riding my bike, I'm walking, I'm moving around in the vineyard, all sorts of things, trying to walk and I think it's given me enough."* (male, 42, prediabetes) *„Well, I like it. I like it for the reason that it forced me every day at first, but now my body demands it. Even if I don't have the time, I'll take that hour to do the circuit that I have here from my house, that's exactly the 10,000 steps."* (female, 61, prediabetes) *„That it's just become a part of my style or my life."* (female, 66, T2D) *„I'm outright lusting after them. now I've gotten used to them and I'm like, if these go away, I'll probably just get one* (Fitbit watch – note)*."* (male, 65, T2D)
		internalization	*„Kind of got me pumped up at first, but then I think I got into this stereotype that I just needed the movement and that maybe I didn't even need the phone calls anymore."* (female, 75, T2D)
External factors - Intervention	all program	a kick	*„…well, of course it's good, because after all, if you want to, it motivates you … how many times maybe I wouldn't even go anywhere and then I go."* (female, 75, T2D) *„.it just really pushes the person a little bit more."* (male, 54, T2D)
		support healthier lifestyle	*„I think that if someone wasn't passionate about the movement, that it could kick-start and motivate them to not get fat, or how to say it. to just support a healthier lifestyle somehow."* (male, 42, prediabetes) *„.this would have been said. so this was supposed to prove that even without the pills, this would help. Definitely recommend."* (male, 54, T2D)
		change of mind	*„Overall, I think that tracking the walking, the number of steps, and the text messages that used to go. I'm going to simplify it now. don't sit for long, you need to take a walk or something like that, I think that it is beneficial because it kind of like wakes you up and nudges you."* (female, 72, T2D)
		under control	*„.it's more that you're kind of a little bit in control."* (female, 69, prediabetes)
		step by step	*„. I was so proud… it was 3000 stpes. Is not much, but I just feel like I'm getting better and it's kind of driving me to do something with the walking."* (male, 75, T2D)
		increase different kind of activity	*„I've increased my activity with this. I use again the bike that's been sitting in the basement for a year. That's great."* (female, 66, T2D)
		the beginning of something bigger	*„My weight was higher, and now I've lost 56 kilos in that six months, but I don't know if it's this, or if I've changed a little. I would say that I'm just kind of following a regimen of eating and everything, so I feel better. I can't say outright that it was because of the study, but I guess maybe it had a little bit of an effect too, because it really does motivated me."* (male, 58, T2D)
		personal	*„.I don't like that. like in front of a group to deal with how much do I weigh. I wouldn't like that. but I like that* (the program – note)*, it is personally just for me."* (female, 56, prediabetes)
		program benefits	*„I wouldn't have minded if it had been longer, and I would say, for me it was a big plus that I could go to the district doctor, where I actually had some kind of check-up."* (female, 61, prediabetes)

Table 1 (continued)

Category	Sub-category	Theme	Quotes
	Fitbit watch	counting	*"Well, I've started keeping track of how much I'm walking, well, otherwise I'm doing nothing but walking in this program."* (female, 59, prediabetes)
		trying to get it done	*„Well, sometimes, when I looked, I was like, well, I haven't been somewhere much today, so I should go again … like I try to get over the 10,000 every day."* (female, 51, T2D) *„If I didn't have that watch on my arm, maybe I would have been lying in that pain otherwise. but I mean. I still wanted to accomplish it, to get it over with so I could be happy, so I got up."* (male, 66, prediabetes)
		enjoying self-monitoring	*"I like the fact that it showed me how many calories I did, how many steps I took, and I just treated it like a game."* (female, 66, T2D) *„I like started tracking it and I started even writing down how much I walked a day."* (male, 63, T2D)
		Self-monitoring	*„.the messages doesn't motivate me, just show me the watch and I know what to do."* (female, 75, T2D)
	telephone counselling	possibility of discussion	*„.the person will call back in if there's a problem. She'll need to explain things like that again. It's motivational, you know. someone's watching, apart from the watch, giving advice and so on. She says, it's all quite fitting, it all fitted together."* (female, 72, T2D)
		human approach	*„Personal contact was much better."* (male, 54, T2D) *„.it was very, very motivating to get that personal, personal call."* (female, 78, T2D)
		confidence	*„I had this feeling right after the first conversation with her. I trust her, or she has some confidence in me, or she compliments me. well she was perfect."* (female, 56, prediabetes)
		add motivation	*„We ended the call and I'm going from room to room and I'm like, yeah, so I could do this. That's how it just affects me when I'm talking to a person."* (female, 57, prediabetes)
		praise	*„I was always looking forward to* *** (telephone consultant – note) *calling me, complimenting me."* (female, 61, prediabetes)
		to show off	*„When she calls, I can proudly say that I'm the action one!"* (female, 51, T2D) *„So it's, it's definitely a good thing and a boost, well, especially if you, as I say, do it well."* (female, 66, T2D)
		under control	*„That someone's checking it out or how should I say it. that's interested. that's asking how it's going, so anyway it's good."* (female, 55, T2D)
		understanding	*„She understood all of my problems."* (male, 76, T2D)
	text messages	reminder	*„Sometimes I'm pumped up and sometimes I'm motivated by the messages that come in. Let me go for a walk etc. That was nice too, I personally kind of liked it."* (male, 54, T2D) *„Well, when the system told me to get up and take a few steps, I was like, well, I better go, because it's probably good for me, so I went."* (female, 56, prediabetes)
		a kick	*„I think that definitely helps sometimes to increase that activity when you're not doing anything, you're sitting at computers and that it kicks in a little bit sometimes."* (female, 61, prediabetes) *„Now I really try to have walking maybe more times, so I think it's good to get those people out of that chair, out of that comfort zone and really think about that movement."* (female, 51, T2D)

> *"I wouldn't have minded if it had been longer, and I would say, for me it was a big plus that I could go to my GP, where I actually had some kind of check-up." (female, 61, prediabetes).*

> *„I guess it's more motivating when you know that somebody is checking on you… it definitely contributes to that." (female, 61, prediabetes).*

Internal facilitators – Intervention

Psychological and behavioural responses to participation in the intervention represented an important source of internal motivation. Participants frequently described a growing sense of control, accountability, and self-regulation, which supported continued engagement.

> *„.maybe it would make me happy to hear somebody say: you're doing well… you're being praised…, I'm doing it for me and somebody else sees it." (female, 55, T2D).*

For many, the intervention facilitated a transition from externally prompted to internally regulated behaviour, characterised by increased confidence in managing their own activity levels without ongoing external prompting.

> *„I have a need to be controlled by someone, but now that I'm used to it, I'll actually have control of myself."*
> *„.okay, now I'm in the study and then I'm not going to do it anymore. but than I really realise that regular exercise should be part of my life. Forever. Let's make it meaningful, right?" (male, 42, prediabetes).*

Table 2 Summary of categories and themes – Receiving text messages (sorted by frequency)

Category	Sub-category	Theme	Quotes
In general	negative	annoying	*„I would rather strongly receive nothing."* (male, 65, T2D)
		demotivating	*„The texts were repetitive. four types of text messages and sometimes I found them kind of demotivating."* (female, 72, T2D)
		repetitive	*„Obviously one piece of information is important to me, but the frequency of then still repeating it. like some retard who didn't get it, so no."* (female, 61, prediabetes) *„I think if you're told the same thing all the time you stop noticing. that it's counterproductive."* (male, 63, T2D)
		burdensome	*„For me, they were burdensome, more like annoying. I was stressed about not being able to just go anywhere and I don't understand when I'm done and the watch knows it. And I'm just at home for a while, like an hour, and after an hour I start getting these texts, I should go somewhere again."* (female, 66, T2D)
	neutral	no influence	*„Probably none, nothing. I just walked how I wanted and when I wanted."* (female, 69, prediabetes) *„I mean, I always read it and forget."* (female, 75, T2D) *„I don't think it affected me. if it was just twice a week, or if it was multiple times, it probably wouldn't have any effect on me."* (female, 51, T2D) *„The messages doesn't motivate me, just show me the watch and I know what to do."* (male, 73, T2D)
	positive	motivating	*„Sometimes I'm pumped up and sometimes I'm motivated by the messages that come in. Let me go for a walk etc. that was nice, I personally kind of liked it.* (female, 55, T2D)
		educational	*„I don't know, I don't remember it that way. you look at it afterwards, but it was great. I learned, I got into the habit of moving around at home more often."* (male, 69, T2D)
		be the part of something	*„I will admit that as good as I felt like I was not alone in this, that someone felt like I was worth checking up on."* (female, 66, T2D)
Receiving JITAI text messages to increase walking pace	negative	upsetting	*„Well, it was upsetting. when I was pedalling up the hill here, I was just huffing and puffing that I'd barely walked and I got message to add. that was the thing that just got to me."* (male, 42, prediabetes)
		demotivating	*„I'm walking as fast as I can!"* (male, 54, T2D)
	neutral	no changes to the routine	*„I guess what works for somebody didn't work for me. I don't know, I really read it and right at that moment I was like, well, I can't do it now. I was doing something on the computer, I got a message, so of course I still had some work to do, so I didn't reflect on it."* (male, 65, T2D)
	positive	motivating	*„Maybe, as you wrote there, that I could speed up, well. so maybe I did speed up for a while, that I came to practice, that I did speed up."* (female, 56, prediabetes)
Receiving JITAI text messages to interrupt the sitting	positive	reminder	*„Well, I'm sure it is. When the system told me to get up and take a few steps, I was like, well, I better go, because it's probably good for me, so I went."* (male, 66, T2D) *„So it's much better because a lot of times you don't realize that you've been sitting for a long time."* (female, 66, T2D)
		motivating	*„Well, it's more of that. if the messages weren't coming, if I wasn't being alerted, I probably wouldn't pick up as often, I wouldn't go, but I think it's beneficial to the person, because it makes them feel like even if they don't want to, they don't have an excuse, like I can't right now or this or that. it's gonna make them go. I'm gonna get up and take that step or go for that walk."* (female, 51, T2D)
		future activity	*„I was more like, oh, I haven't been anywhere today, so then maybe I went in the afternoon, but mostly, every time the messages came, I couldn't go right away."* (female, 75, T2D)
	neutral	no influence	*„.so I just normally ignored it, it limited me when I just needed to spot."* (female, 75, T2D)
		no changes to the routine	*„I read them and I just ignored that because I know I'm going to go for a walk in an hour, Now I'm doing something else. so it didn't affect my schedule."* (female, 56, prediabetes)
	negative	bad timing – personal reasons	*„I will be 78 years old. that's the age when I have a certain, set, just daily regime. and I get them* (message – note) *in the evening when I am already quiet, I sit down in front of the TV and I don't really want to go anywhere anymore."* (female, 78, T2D)
		bad timing – work reasons	*„When I have a job in the office, I can't walk away from it. so I'm not gonna go for a quick walk. I'll just find the time. But not when I get the message."* (female, 59, prediabetes)
Evaluation feedback messages	positive	motivating	*„That would motivate me, I just always wanted to achieve as much as I could, so I was trying all the time, every day to achieve as much as I could."* (female, 55, T2D)
		motivating to regularity	*„I was always quite excited to see how many it would count."* (female, 66, T2D)
		inspiring	*„That's good to remind. so it's nice to say, if you didn't do well during the week, now add at the weekend. so I smile and say yeah."* (male, 54, T2D)

Table 2 (continued)

Category	Sub-category	Theme	Quotes
		confirmation	*„It was more motivating, because it makes you feel good that I was good this week. so it's kind of nice when you think, I didn't mess up, so I can prove to myself that maybe I could have done better. So I think it's good."* (female, 56, prediabetes)
	negative	demotivating	*„It was demotivating. if I could, I'd probably jump up and go like this, I'd say."* (female, 61, prediabetes)
Educational messages	neutral	lack of interest	*„I don't realize those stats anyway. I might. when I see this one over here, I don't even read."* (female, 57, prediabetes)
		nothing new	*„I think it's just common knowledge this thing."* (female, 66, T2D)
	positive	internalization	*„I think it's good that at least the person realizes again why he's doing it actually. that he's really doing it for his health, that he's not just doing it for the study or for the doctor. that he's doing it for himself."* (female, 69, prediabetes)
	negative	repetitive	*„I know that exercise is important and healthy and necessary and a lot of diabetics take insulin and all sorts of stuff. No one has to tell me that twice, every week."* (male, 54, T2D)

„It made sense, it made sense for me, so I consider that year to be enough because it showed me a certain path." (male, 73, T2D).

External facilitators - Intervention

Many participants expressed that the entire ENERGISED program helped them "kick start" some activities, leading them to adopt a healthier lifestyle.

„.especially the motivation, that's important from my point of view, that you need a little push." (male, 76, T2D).

Specific intervention components acted as key external facilitators. The Fitbit device was widely perceived as the most influential motivational element, enabling self-monitoring, goal tracking, and immediate feedback.

„.especially the bracelet was able to motivate me to move more, to be more physically active, and I've seen that I was missing the steps, right, so I tried to walk it, it was perfect." (male, 63, T2D).
„I like to get things done, right, what's in front of me, and that was kind of a challenge for me, it was influencing me, the watch was motivating me." (female, 61, prediabetes).

Telephone counselling added a relational and supportive dimension, enhancing motivation through human contact, encouragement, and perceived accountability.

„Those consultations are totally different than the texting, there's a lot of things you can say. When it's spoken talking it's so enjoyable." (female, 72, T2D).

Text messages were viewed more variably. Feedback messages on progress were often seen as motivating and reinforcing regularity. The JITAI prompts, a novel feature of the program, were consistently perceived as helpful reminders that supported short-term behavioural regulation by interrupting prolonged sitting. Most participants considered the stand-up reminder well-timed. For some, if it was not possible to interrupt sitting then and there the message acted as a reminder to move in the future.

„We've been sitting here for a long time, so I was glad that something alerted me that I should move." (female, 66, T2D).
„. when it pings you like that and says you've been sitting for a long time, well, you'll forget. It's a really good thing." (female, 56, prediabetes).
„So these messages, as you asked, mostly motivated more of that walking." (male, 54, T2D).

Six participants reported not receiving JITAI messages at the right time, often when they were unable or unwilling to interrupt their sitting due to personal routines or work. Four participants were indifferent to the timing of these messages.

„Sometimes I would just get up and go do something, or at least walk around a bit when it came up, when I was at home. But sometimes I was sitting at the computer doing something, I needed to get something done, so I just ignored the message… well, you just can't do that sometimes." (male, 66, prediabetes).
„I have a visitor here, I can tell the visitor, don't be mad, I need to be walking." (female, 66, T2D).

In contrast, JITAI messages prompting faster walking pace produced mixed responses. Even though almost half of the participants commented that the timing of the messages was appropriate, there were two main barriers to engaging with these messages; firstly (and most commonly), respondents had subjective, but sometimes also objective reasons (mainly health) for claiming that they could not go faster for a longer period. This made it impossible for them to respond to the messages as

Table 3 Summary of categories and themes – Barriers to engaging with PA and the intervention

Category	Sub-category	Theme	Quotes
Internal factors - PA	own health	pain	*„I tried to run, but then my back started to hurt."* (female, 56, prediabetes)
		limitation	*„I've actually lived with that movement my whole life, so I've been used to it, so for me that movement changes is not the problem, I was used to. I'm limited with my legs. well, I can't do what I want to do."* (female, 69, prediabetes) *„It's just that the body doesn't react the way a healthy person does, I have bad liver tests, right, so sometimes I'm like a surplus of strength, sometimes I'm like seventy years old. I knew who I was dragging, and I couldn't do it if I wanted to a hundred times… so I do what I can. "* (female, 72, T2D)
		heart condition	*„I have two heart attacks in a row, angina pectoris, so when the wind blows I hardly go out, it's getting me down, so some objective difficulties like that."* (male, 75, T2D)
	established routine	already active	*„I've cycled somewhere, I don't know. 50, 80 km, so I'll arrive in the evening and I won't walk another 10 km, walk somewhere, I've had enough."* (female, 61, prediabetes) *„I didn't need anything specific to do that because I just try to do sports even from that, I go cycling, skiing and I especially like to go for walks, so it just feels like normal, natural to me even from here today. "*(female, 66, T2D)
		already established routine	*„Sometimes I've tried to increase frequency, but mostly, I just have my own pace, especially with the dog. So, when I do that walk I kind of have it interspersed with faster walking, but totally just kind of slow."* (female, 51, T2D)
	prioritizing others		*„I want everyone to have a good time, and then I think about myself, which is probably not good either. I don't have that space for myself everywhere."* (female, 51, T2D) *„I don't always have that much time to myself. I don't care if I go somewhere every day, but I just couldn't always do it."* (female, 56, prediabetes)
	no changes in lifestyle		*„Not at all. I think, I would have the same lifestyle and whether I had the watch or not, I would probably do everything the same way."* (male, 66, prediabetes)
		do not want to change	*„I just said, so just walk as I can, as I can and it didn't affect me, I don't know, it didn't affect me in any way."* (female, 66, T2D)
	lack of self-motivation	laziness	*„When I've had my dinner and I'm so lazy, I'm looking forward to watching TV, well, I don't think anything would make me get up and go for a walk."* (male, 66, T2D)
External factors - PA	weather		*„I say it's all weather dependent."* (female, 61, prediabetes)
		cannot go out because bad weather	*„And a couple of days it was icy, so maybe I wasn't out at all. Better weather, so I'm walking more and more."* (male, 76, T2D) *„And yet I'm of a certain age. And when the weather was abnormally bad, I didn't leave the house."* (female, 78, T2D) *„In the winter, they wanted I wouldn't have done so many steps I had because there were frosts."* (female, 69, prediabetes) *„Now over the winter, when the snow is like this, I hardly go out."* (female, 80, T2D)
		do not want to go out because of bad weather	*„Sometimes the weather was bad, sometimes when I was a bit tired I didn't feel like it."* (female, 55, T2D)
	work reasons	bad timing	*„You should walk, you should speed up. I know, but if you can't, you can't.* (teacher during class – note)*"* (female, 66, T2D)
	time	lack of time	*„But I knew that just time-wise sometimes I can't make it, I'm at work late and that week about time-wise. not that I like don't want to, but I just don't have time and now even when I'm having early, I don't want to just go out for an hour after I just get home."* (female, 56, prediabetes)
Internal factors - Intervention	barriers to engaging with text messages	don't have phone with all the time	*„So I guess it's a good program, a necessary program, and I'm happy to participate in it, except sometimes I get this weird feeling when I don't notice because I'm not on my cell phone all the time, I don't look at it all the time. I don't notice when it is just texting me to go faster, it text me to speed up."* (female, 75, T2D) *„I can't say, because I'd have to have the cell phone glued to me. as I tell you, so many times the messages come in and I'll admit the next day."* (male, 76, T2D)
	Fitbit watch problems	hard to see	*„I used to get one of those for a week where it recorded all sorts of things, but these glasses, you can't see it that well. in the daytime you just take the glasses when maybe there's more light, so if they were like, I don't know, double the size and bigger the display."* (female, 66, T2D)
		hand problems	*„I have problems with the carpal tunnels in my hands, so I didn't wear the watch at all, but I have to. now I'm into it, so. well, that's it."* (male, 69, T2D)
External factors - Intervention	barriers to engaging with text messages	need to have smartphone	*„Who doesn't have that smart phone. that it's a certain disadvantage."* (female, 80, T2D)

Table 3 (continued)

Category	Sub-category	Theme	Quotes
		no data	*„Well, I've ignored 50% of it completely because the watch is data dependent and I don't have data on my phone so everything loads when I get on wifi home, secondly it's over the bluetooth it's still a flashlight, so I've been turning it off and loading it up at like 9 o'clock at night and winding it up on the phone."* (female, 75, T2D)
	Fitbit watch problems	records only walking	*„When I was exercising, it didn't register there, it would have to switch to some other mode probably."* (female, 61, prediabetes)
	suggestion for improving the energised program	another intervention components	*„When you asked what would be beneficial. maybe even like a menu. My point is restricting some diet or whatever as not downright as much appropriate when one probably knows it, but maybe when reminded of it, they'll change their mind, then maybe will be eat better."* (female, 59, prediabetes)
		another type of messages	*„Maybe they could post the messages to maybe describe a specific exercise. One that could be applied to make the musculoskeletal system even better."* (female, 66, T2D)
		encouragement for other activities	*„I missed some of that. we were in the mountains, I skied every day, we skied 20 km and I didn't find anything. Like, you're excellent or well you had that activity now maybe every day, so I didn't find that. Somebody might be upset, I don't make a big deal out of this. just like, if you're asking, maybe some kind of encouragement."* (male, 54, T2D) *„So there's this thing which is kind of strange to me, because the programing prefers that kind of non-productive activity, that I go somewhere or play sports, but I had quite a bit of physical work over the summer, and it almost doesn't take."* (male, 54, T2D)

intended in the intervention. The second barrier was an unwillingness to change their behaviour due to their lifestyle associated with regular activities. For five participants, the timing was inappropriate, participants complained that the messages would come when they cannot or do not want to increase their pace. Five participants did not care about the timing and five did not know.

> *„It didn't affect me, it pissed me off because I was doing the best I could. I should have been walking what I can handle with the diabetes. Not having somebody chasing me. like I'm not going to run, I couldn't even with the weight." (male, 63, T2D).*

A few participants said the JITAI messages served as a helpful reminder and a boost to increase their activity.

> *„Sometimes the message kicked me in that I thought yes, I can add a little for a moment." (male, 76, T2D).*

Barriers to engaging with physical activity and the intervention

Internal barriers - PA

The most prominent internal barriers to PA were health-related limitations, including musculoskeletal pain, cardiovascular conditions, fatigue, and reduced mobility. These constraints often restricted participants' ability to increase intensity or duration of activity despite strong motivation.

> *„. sometimes the pain limits me…sometimes you just can't." (female, 57, prediabetes).*

> *„ My feet hurt so much…I'm happy to walk with the kids and then I'm happy to sit down. " (female, 69, prediabetes).*

Established daily routines, the belief that one's current lifestyle was already sufficiently active, and occasional low self-motivation further limited engagement in additional PA.

> *„ I'm just moving from morning to night and then in the evening I'm happy to sit down " (female, 69, prediabetes).*

External barriers - PA

External barriers primarily reflected environmental and time-related constraints. Adverse weather conditions, particularly during winter months, substantially reduced outdoor activity.

> *„From spring to autumn, I was showing good results compared to winter, well, there's not as much exercise, there's not as much opportunity." (female, 78, T2D).*

Work responsibilities and lack of free time were recurrent obstacles, especially among working participants, limiting their ability to respond to activity prompts during the day.

> *„Sometimes it [the prompts] came when I was driving in the car (truck driver – note), I really couldn't." (male, 42, prediabetes).*
> *„I was doing something on the computer, I got a message, so of course I still had some work to do." (female, 61, prediabetes).*

Internal barriers - Intervention

Some participants experienced internal barriers related to engagement with intervention tools, particularly low technological confidence or reluctance to interact frequently with digital devices.

> *„ I'm not really a phone person… I don't watch the phone that often." (female, 75, T2D).*

A few participants reported physical discomfort or usability issues associated with the Fitbit, which reduced effective use of the device.

> *„… for older people who can't see very well it's so small." (male, 66, T2D).*

External barriers - Intervention

External barriers related to the intervention included technical issues (limited mobile data, delayed synchronisation, or lack of smartphone ownership), as well as timing and perceived burden of text messages.

> *„I get one single text message that it helps. So I take it that way and I don't need to hear it anymore. If I get it a hundred times, I don't care because one is enough for me." (male, 58, T2D).*

Some participants reported that messages arrived at inconvenient moments or were perceived as repetitive. Others expressed frustration that the system recorded walking only and did not adequately capture other forms of physical activity (for example swimming).

> *„ I had quite a bit of physical work, and it almost doesn't take." (female, 51, T2D).*

Suggestions for improvement were relatively rare but included incorporating dietary guidance, broader exercise options, and more immediate positive feedback for high activity levels.

Summary of findings

Overall, participants' engagement with the ENERGISED intervention was shaped by a dynamic interplay between internal health-driven motivation, the supportive structure of intervention components, and contextual barriers related to health, environment, and technology. Wearable self-monitoring and telephone counselling emerged as the most robust facilitators of sustained engagement. By contrast, health limitations, weather, time constraints, and digital accessibility issues were the most persistent barriers. JITAI messages showed differentiated effects depending on behavioural target and context, with prompts to reduce sedentary time being more consistently acceptable than prompts to increase walking pace.

Discussion

Principal findings

This qualitative investigation examined facilitators and barriers to PA and the intervention as part of a process evaluation of an mHealth intervention aimed at increasing PA and reducing sedentary behaviour among those with T2D and pre-diabetes. We assessed individual intervention components, including the Fitbit watch, telephone counselling, and text messages including JITAI messages. Health status was the strongest motivator but also a barrier to increasing activity. Most participants found the intervention supportive. The Fitbit watch and telephone counselling were perceived to be particularly effective motivators. Participants also responded positively to immediate feedback, such as high step counts, which reinforced engagement and adherence. A key novel aspect of the ENERGISED program was the use of JITAI messages, which provided real-time, context-sensitive prompts to interrupt prolonged sitting or encourage step goals. The feedback on the JITAI messages was mixed; participants felt that they encouraged them to interrupt prolonged sitting, which is crucial as extended sitting can be harmful to pre/diabetics [1, 4]. However, messages to increase walking pace had less influence, as participants perceived this as unsustainable.

Comparison with other studies

Our study found that responsibility for one's health was a major motivator for increased PA, aligning with research by Avery et al. [17] and Miquelon and Castonguay [18], which highlighted that individuals with chronic conditions like diabetes often feel a strong personal responsibility to manage their health, driving their PA engagement. Self-efficacy and the ability to maintain healthy behaviours also emerged as significant internal motivators, consistent with findings from other studies [19, 20], who emphasised the importance of self-efficacy. Wahlich et al. [21] further supported the role of internal motivation in sustaining PA post-intervention. Interestingly, in contrast to previous studies, extrinsic motivators did not play a significant role in adherence to the ENERGISED program. This finding contrasts with previous research by Pavey et al. [22], who reported that external reinforcement, such as encouragement from healthcare providers, significantly enhanced long-term adherence to PA programs. While other studies [7] have shown that external incentives such as social support or professional recommendations influence participation in PA programs, our participants relied predominantly on intrinsic motivation. This could suggest a potential shift in factors that influence long-term adherence in this population

and our results are thus more consistent with the work of McNeill et al. [23], who suggested that intrinsic motivation plays a more critical role in the maintenance of PA, especially in older populations.

In the realm of digital health interventions, particularly JITAIs, our study adds to the growing body of evidence suggesting that these interventions offer a useful way to increase PA in at-risk populations. For example, a study by Spring et al. [24] investigated the use of JITAI to promote PA in adults with obesity and found that the intervention significantly increased daily steps. This finding is similar to our results, where participants responded positively to JITAI messages encouraging them to break long sitting sessions or increase their walking pace. However, the influence of these messages varied based on context and timing. Participants also highlighted unanticipated benefits of the program, such as more frequent visits to their GP.

Qualitative research conducted by Fischer et al. [25] further supports the utility of JITAI in promoting PA. Their study explored user experiences with JITAI interventions among adults with chronic conditions and found that context-sensitivity and personalisation of messages were key factors in enhancing engagement and motivation. Our study aligns with these findings, particularly in how participants appreciated the personalised aspect of the intervention, although some reported challenges related to message timing and perceived relevance.

In contrast to a systematic review of barriers and facilitators to PA, which identified lack of time as the primary barrier to PA [26], participants in our study predominantly cited their health status. This discrepancy may be attributed to differences in the samples studied, as our participants were individuals already diagnosed with prediabetes or T2D. Nevertheless, the review also highlighted health status as the second most frequently mentioned barrier to low PA. Additionally, while the review identified negative emotions as the third most common barrier, we observed this factor less frequently among our participants.

The barrier of perceiving one's lifestyle as sufficiently active, which we identified as a significant obstacle to increasing PA, has also been documented in other studies. For example, Normansell et al. [7] found that participants often overestimated their activity levels, potentially discouraging them from engaging in additional exercise. This cognitive bias represents a substantial challenge and the need for objective self-monitoring to provide an accurate and unbiased measure of PA behaviour and outcomes.

Weather conditions were another major barrier identified, particularly bad weather, which discouraged participants from engaging in outdoor PA. This finding is consistent with the results of King et al. [27] who reported that inclement weather significantly reduced PA levels in older adults, particularly during the winter months. Our study further supports the conclusions of Tucker and Gilliland [28] who suggested that interventions should include strategies for indoor or alternative activities to mitigate the impact of poor weather. The impact of adverse weather conditions on PA adherence highlights the need for flexible intervention strategies that can respond to environmental challenges.

Perception of time constraints, particularly among working participants, was a notable barrier to PA in our study. This finding aligns with the work of Trost et al. [29]. Our results suggest that future interventions should consider flexible scheduling and time management support to address this pervasive issue.

Importantly, the use of smartphones and other digital tools presented challenges for some participants, especially older adults. This is consistent with the findings of Vaportzis et al. [30] who reported that while older adults are increasingly using digital devices, many still face barriers related to usability and trust. Our results echo calls for more tailored digital interventions that take into account the technology comfort level of the older population, as highlighted by Chen and Chan [31]. Given that our sample had a mean age of 64.4 years, these challenges are particularly relevant, indicating that alternative approaches—such as comprehensive training on smartphone use or a combination of digital interventions with human support or non-digital strategies—may be necessary for this demographic.

Strengths and limitations

To explore motivations, facilitators, and barriers to PA within the ENERGISED intervention program, qualitative interviews are an effective method for gathering opinions on engagement and adherence. The qualitative data provided insight into individual experiences, allowing us to build on previous focus group interviews [32] and delve into specific aspects of the intervention, including detailed feedback on the novel JITAI messages.

The sample size was relatively large (n = 27) and comprised men and women of different ages. Theoretical models suggest that 27 participants are an optimal sample size for qualitative research [33–35]. We included the perspectives of both low and high adherents to the intervention to ensure a comprehensive understanding of the program, regardless of participants' performance levels.

Qualitative research relies on researcher interpretation and is therefore vulnerable to bias [36]. To minimise this, two researchers (KJ and CW) independently analysed all interviews [15]. The emerging topics were then discussed with the wider research team, and although no coding discrepancies arose—removing the need for a third reviewer—this high level of agreement also meant

the study did not benefit from full researcher triangulation. Nonetheless, this collaborative approach enhanced the trustworthiness and credibility of the analysis [16], and verbatim quotations are provided to support transparency and strengthen interpretive validity.

Several methodological limitations should also be acknowledged. Data collection relied solely on telephone interviews, which may have constrained rapport, limited observation of non-verbal cues, and reduced contextual richness compared with in-person or online approaches. Participant validation (member checking) was also not undertaken, restricting the ability to confirm the accuracy of interpretations directly with participants. As with all research of this kind, the findings represent only the views of those who agreed to take part; because individuals who declined to participate were not interviewed, reasons for non-participation remain unknown. Finally, knowledge of findings from an earlier qualitative focus group study conducted prior to this intervention [32] may have influenced interpretation despite efforts to bracket pre-existing expectations [37].

Taken together, these methodological constraints may affect the credibility and transferability of the findings and should be considered when interpreting the results.

Although it is unlikely that our findings can be generalised to all those who participated in the ENERGISED program, they provide a unique insight into the reasons for better or worse adherence to the program, or to PA, and at the same time to the effectiveness of the intervention and its components. The generalisability of these findings is uncertain, but it seems plausible that some of the reasons mentioned (e.g., health status) may also represent barriers to increasing PA outside the research environment.

Conclusions

This qualitative study explored participants' experiences with the ENERGISED intervention, focusing on motivations, barriers, and engagement in increasing PA and reducing sedentary behaviour among individuals with prediabetes and T2D. Participants were primarily motivated by personal responsibility for their health, and the intervention's impact varied across components. Fitbit devices and telephone counselling were the most effective, supporting behaviour change, accountability, and sustained PA.

The JITAI messages, a unique and innovative component of the ENERGISED program, were generally perceived as motivating, particularly those prompting interruptions to prolonged sitting or providing step-count feedback, while messages encouraging faster walking pace were less useful. Participants' experiences were similar regardless of step-count changes, indicating perceived benefits independent of measured activity.

Overall, the program was well-received and positively influenced daily PA. The findings underscore the acceptability of mHealth interventions, the value of personalised and context-sensitive approaches, and the need to optimise JITAI content and support for older adults facing technological challenges. These insights inform the design and implementation of future interventions for individuals at risk of or living with T2D.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Authors' contributions

Conceptualisation: KJ, TV, MP, NK, MU, IM, DVD, SE, JP, MS, BS, TY, TH, CW. Data curation: KJ, JN. Formal analysis: KJ, CW. Funding acquisition: TV, RC, BS. Investigation: KJ, CW. Methodology: KJ, TV, MU, TH, CW. Project administration: TV, JN, JK, MP, NK, KM. Resources: TV, JN, JK, MP, NK, KM, RC, BS. Software: JK, RC. Supervision: TV, MU, BS, TH, CW. Visualisation: KJ. Writing - original draft: KJ, CW. Writing - review & editing: all authors.

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Data availability

The datasets generated during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study protocol has been approved by the Ethics Committee of the General University Hospital, Prague (No. 49/20), and the study was conducted in compliance with the principles of the Declaration of Helsinki. Informed consent to participate in the study was obtained from participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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