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Preliminary Results of the Evaluation of an Integrated Intervention Combining a Digital Platform, an Interdisciplinary Team, and Peer Support for People Listed for Liver Transplantation: A Longitudinal Mixed-Methods Study

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Abstract

Background

Candidates for liver transplantation often present with frailty and functional deconditioning that can compromise their pre-transplant trajectory. The transplant Action Connected program in liver transplantation (TAC-Liver graft) offers an integrated connected prehabilitation intervention combining a digital platform, connected devices, personalized physical activity and nutrition goals, interdisciplinary follow-up, and support from peers who have experienced transplantation. This model aims to support self-management, continuity of follow-up, and functional preparation while awaiting transplantation.

Objectives

To evaluate, in a mid-study preliminary analysis, an integrated prehabilitation intervention for patients awaiting liver transplantation that combines peer support, a digital platform with connected devices, and interdisciplinary follow-up.

Methods

A prospective longitudinal mixed-methods study was conducted among 24 pre-transplant participants. Quantitative data included daily step counts, achievement of individualized walking goals, and the Liver Frailty Index (LFI), measured at enrollment and at three months. A classification of step trajectories, established through group-based trajectory modeling among 45 patients, was applied to the 24 participants. Forty-eight interviews conducted at approximately six weeks and three months were thematically analyzed and then integrated with the quantitative data in an individual longitudinal matrix.

Results

The mean observation period was 141 days (SD = 106.1). Among participants, 17 (70.8%) showed a stable step trajectory, 6 (25.0%) an increasing trajectory, and 1 (4.2%) a decreasing trajectory. Daily step goals were met on average during 74.5% of observed days. Among the 23 participants with two LFI measurements, the mean LFI decreased slightly from 3.64 to 3.54, with both mean values remaining within the pre-frail range. At the individual level, 15 participants (65.2%) had a lower LFI at three months, 1 (4.3%) remained unchanged, and 7 (30.4%) had a higher LFI. Data integration showed that stability in step counts could coexist with functional improvement. Interviews indicated that connected devices supported self-monitoring, routines, motivation, and a sense of security, but their usefulness was limited by technical issues and incomplete measurement of certain activities. The interdisciplinary team played a central role in personalizing and ensuring the safety of goals. Peers mainly provided emotional and experiential support, while family members offered daily and logistical support.

Conclusions

These preliminary results suggest that connected, interdisciplinary prehabilitation can support the maintenance of activity and potentially favorable changes in functional before liver transplantation. However, step count alone does not fully reflect clinical progress and must be interpreted alongside the LFI and qualitative data.

INTRODUCTION

Liver transplantation is the only potential cure for end-stage liver disease [1], and the period preceding transplantation remains marked by significant clinical [2], functional, and psychosocial vulnerability [3]. Advanced liver disease is frequently accompanied by sarcopenia, with prevalence estimates ranging from approximately 20% to 70% depending on the population and diagnostic criteria [4], as well as by malnutrition [5, 6], significant fatigue [7], physical deconditioning, and overall frailty, all of which are associated with poor prognosis [8]. For more than a decade, the literature has shown that frailty is common among liver transplant candidates and predicts waitlist mortality independently of the severity of liver disease [9, 10]. In this population, frailty can be objectively assessed using the Liver Frailty Index (LFI), which combines grip strength, timed chair stands, and balance testing to provide an objective measure of physical frailty [10].

This recognition of frailty as a major determinant of pre-transplant trajectories has fostered the emergence of the concept of prehabilitation. In the surgical field, prehabilitation aims to optimize functional, nutritional, and psychological status before a major intervention in order to improve tolerance to operative stress and clinical outcomes [11]. In liver transplantation, patients are often exposed to prolonged waiting periods, repeated episodes of decompensation, and a progressive loss of autonomy [12, 13], so prehabilitation interventions in these patients appear relevant and safe, even though the evidence remains limited and the strategies evaluated heterogeneous [14].

Within prehabilitation programs, physical activity and functional reconditioning play a central role. In patients with advanced liver disease, physical inactivity, sarcopenia, and frailty are associated with increased morbidity [2, 15] and mortality [8]. Several trials and pilot studies suggest that exercise programs [16], including home-based interventions [17], can improve certain indicators of physical capacity, quality of life, or frailty. However, implementing lifestyle changes can be particularly challenging for patients living with cirrhosis [18].

This issue is even more important pre-transplant, as patients face fatigue, ascites, fluctuating symptoms, hospitalizations, uncertainty related to transplant timing [3], a significant emotional burden [19], and increased dependence on their family members [20]. In practice, improving health status before transplantation is therefore not simply a matter of recommending more exercise or dietary changes; it requires a care model capable of supporting patients in sustained lifestyle change, personalizing goals, providing concrete feedback, and reducing organizational barriers.

One way to foster these behavioral changes is through the use of digital solutions [21–23]. Connected devices, telemonitoring, and digital platforms enable home-based follow-up of people living with chronic disease, including in the field of transplantation. In hepatology, these tools can facilitate symptom monitoring, support self-management, and strengthen continuity of care [23, 24]. Several pilot studies have reported positive results regarding the feasibility and acceptance of digitally enabled home support programs [21, 22, 24]. However, the evidence remains anecdotal, focused on a single component of the intervention, and provides little detail on the integrated clinical models used.

Another possible avenue to improve patient outcomes is care and service partnership [25, 26], and more specifically peer support, which allows people who have already gone through a care journey to draw on their experiential knowledge to help others who will go through a similar trajectory [27, 28].

Finally, the organization of the pre-transplant journey (work-up before listing and follow-up after listing) is often fragmented. Patients face multiple medical, nursing, nutritional, and psychosocial consultations spread over several weeks, or even several uncoordinated months. This can delay certain steps [29] and make the journey more confusion for patients and their families [19, 30].

To address these challenges, the Transplant Action Connected program in liver transplantation (TAC-Liver graft) was implemented at the Centre hospitalier de l'Université de Montréal (CHUM) to improve care coordination and support patients in changing their lifestyle habits. This program is based on an integrated intervention consisting of a digital platform accessible via computer, tablet, and phone, connected devices such as a watch, a blood pressure monitor, and a scale, as well as support from an interdisciplinary team including physicians, nurses, nutritionists, kinesiologists, and peer accompanying patients [31].

The objective of this study is to present the preliminary results of the evaluation of the prehabilitation model developed as part of the TAC-Liver graft program for patients awaiting liver transplantation.

METHODS

Study design

A prospective longitudinal mixed-methods design was used to evaluate the early effects of the intervention and the situations likely to explain the observed changes [32]. The mixed-methods approach aimed to link the evolution of certain behavioral and clinical indicators with patients' personal experiences, their perceptions of the intervention, and the factors likely to support or, conversely, hinder their engagement in the program [31]. The study was conducted in accordance with the Declaration of Helsinki and the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2, 2022)* and received ethical approval from the Research Ethics Committee of the Centre hospitalier de l'Université de Montréal (CHUM; project no. 20-5185). All participants provided written informed consent before participating in any research activities.

Study setting

The study was conducted within the liver transplantation program of the CHUM, as part of the Transplant Action Connected program in liver transplantation (TAC-Liver graft). This program covers the period from the work-up for transplant listing to one year post-transplant and combines a digital platform, connected devices, and an interdisciplinary team (physicians, nurses, nutritionists, kinesiologists, peer accompanying patients). For the period from listing to transplantation, the patient is supported by an interdisciplinary team composed of hepatologists (n = 12), nurses (n = 2), a nutritionist (n = 1), a kinesiologist (n = 1), and accompanying patients (APs) (n = 6).

When the patients are listed for transplantation, they are seen during a so-called "Day Zero" visit, during which the following are established: the treatment plan with a nurse, the physical exercise plan with the kinesiologist, and the nutritional plan with the nutritionist. These plans are co-constructed with the patients [31] and developed using a motivational interviewing approach [33]. This allows patients to set their own goals in terms of physical exercise and dietary change while benefiting from professional support. In addition, an accompanying patient (AP) is assigned to support patients in carrying out their exercise and nutrition plans and to provide emotional support.

In addition, during this meeting, they are provided with three connected devices (a CareSimple® 4G scale (Best value/Max 440lbs), a CareSimple® 4G blood pressure monitor (9–18" cuff), and a Garmin vívosmart 5 or Garmin vívosmart 4 watch) so that, on one hand, patients can track the impact of their behavior on their health and, on other hand, professionals can intervene remotely in the event of a change in physiological parameters or non-adherence to the plans. Patients can view the data from their three connected devices directly on their smartphone (see Fig. 1) or on the CareSimple® digital platform (see Fig. 2). When the patient returns home, they receive phone calls from the kinesiologist and the nutritionist each month for the first three months, and medical follow-up is provided through an in-person consultation every three months. Monthly follow-up is carried out by the nurse and the AP throughout the program. In all cases, professionals can be contacted on request between pre-established times.

Study population

The study aims to include 60 patients to evaluate the TAC-Liver graft program; recruitment began on April 23, 2024, and complete two-year follow-up is expected to end in April 2027. Before results for all 60 patients become available, we conducted an initial descriptive mid-study analysis of a sample of 24 pre-transplant patients. These participants were selected because: 1) they completed two interviews: the first approximately six weeks after being seen in consultation and receiving the connected devices, and the second approximately six weeks after the first; 2) they have data from their connected devices spanning at least two weeks, allowing daily physical activity variations to be tracked. Paired Liver Frailty Index (LFI) measurements, a prognostic measure based on objective clinical parameters used to assess frailty in patients with advanced liver disease [10], were available at transplant listing (T0) and three months later (T2) for 23 of the 24 participants; one participant had missing LFI data.

Quantitative data collection

Two types of quantitative data are collected as part of this project.

1) Physical activity is measured by the number of steps recorded by the connected watch. These data are collected continuously and stored on the CareSimple® server.

2) The Liver Frailty Index (LFI) is based on a standardized frailty assessment protocol comprising three main tests: grip strength, timed chair stands and balance testing. Grip strength is measured with a dynamometer, timed chair stands assess the time required to complete five consecutive stands without using the arms, and balance is evaluated by assessing the ability to maintain side-by-side, semi-tandem, and tandem positions. These measures together provide a standardized assessment of physical frailty.

This composite indicator provides information that complements liver function alone, incorporating non-hepatic and functional dimensions relevant to transplant candidates. In the context of a connected prehabilitation intervention, the expected outcome is a stabilization or decrease in the LFI score over time, reflecting, respectively, maintenance or improvement of physical frailty status during the pre-transplant period. This expectation is clinically relevant, as frailty measured by the LFI is associated with waitlist mortality independently of the severity of liver disease [10, 34]. Thus, in this study, a decrease in LFI or stabilization was interpreted as a favorable change in frailty, given the high risk of deconditioning and functional decline among patients awaiting liver transplantation [10, 34, 35].

Qualitative data collection

Interviews were conducted with the 24 patients at T1 (approximately six weeks after transplant listing) and T2 (three months after listing). These interviews aimed to explore patients' experience within the program and to better understand the mechanisms that might explain the changes observed in the quantitative data.

The interviews covered four different themes: 1) the reasons that may explain an increase or decrease in step count, 2) perceived changes in lifestyle habits, 3) the evolution in perception of the contribution of connected devices, and 4) the role of APs and connected devices in the care experience and follow-up. The interview guide is presented in Appendix 1. It includes questions for pre-transplant patients at T1 and T2, as well as questions addressed to family caregivers at T2.

Patients received an information form and signed consent for the use of their data.

Quantitative data analysis

● Physical activity

To analyze patients' physical activity, we used a methodology to classify patients according to their ability to reach their goals. This methodology was carried out in two steps. The first step consisted of determining an optimal classification of the daily step count for all patients recruited up to December 31, 2025 (n = 53), and the second step consisted of classifying the study subsample (n = 24) included in this article relative to the reference classification obtained in the first step.

- First step: determining the classification

The first step aimed to identify patient classes based on daily step counts recorded by the connected watch on the CareSimple® server, in order to reveal typologies of patient behavior.

Classification was performed in R statistical software (version 4.5.2; R Foundation for Statistical Computing, Vienna, Austria) on the 53 patients enrolled as of December 31, 2025 (the study's midpoint). Of these, 4 had no watch data (emergency transplant) and 4 had been enrolled for less than 14 days and had not yet generated sufficient data; 45 patients thus had continuous data over at least 14 days (17 to 396 observation days).

Using these 45 patients' pre-transplant data only, we applied group-based trajectory modeling (GBTM) in R [36, 37]. Daily step counts were log-transformed to limit the influence of extreme values and improve residual normality [38], and follow-up time was normalized to a [0,1] interval (0 = start of device use, 1 = end of individual pre-transplant follow-up) to account for varying observation durations.

R was run sequentially for 1- to 4-class solutions, selected using: (i) AIC/BIC values; (ii) posterior classification probabilities, with higher averages indicating greater certainty; and (iii) minimum class size, as solutions with very small groups (typically fewer than five participants) are considered statistically weak and excluded [39].

The three-class model showed the best fit (AIC = 18,613.9; BIC = 18,621.1), with average posterior probabilities of 99.9%, 98.2%, and 98.5% for classes 1–3, and over 96% of participants per class above 0.7. It was retained as optimal, distinguishing an increase class (step count + 225%), a "stable" class (-25.6%), and a "decrease" class (-86.5%).

- Second step: Assessment of step-goal achievement among study participants

In addition, for the 24 participants who completed interviews at T1 and T2, we calculated, for each pre-transplant week (7 days), the proportion of days on which the individualized step goal co-defined with the pre-transplant nurse and kinesiologist was achieved. For example, if a patient reached the goal on two days during a given week, the weekly goal achievement rate was calculated as 29%.

● The Liver Frailty Index

The LFI score is assessed by the pre-transplant nurse at the time of listing (T0) and then repeated three months later during the medical visit (T2). It includes the three standardized tests (grip strength, chair

stand test, and balance assessment).

At the individual level, changes in the LFI score between T0 and T2 were classified into three categories: improvement when the value decreased, stable when unchanged, and worsening when it increased. This categorization made it possible to classify the 23 participants into three trajectory profiles for each of the two indicators. At the group level, mean values and standard deviations of the tests were also compared between T0 and T2.

Qualitative data collection and analysis

Interviews were conducted between November 11, 2024, and February 23, 2026. They were carried out by videoconference and by phone, with an average duration of 20 minutes. Interviews were recorded with participants' consent, fully transcribed, and then de-identified prior to analysis to allow for systematic analysis. The conduct and presentation of the qualitative approach were guided by the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist [40].

The data underwent a thematic analysis combining a deductive and inductive approach [41, 42]. Transcripts were first read multiple times to allow familiarization with the corpus. An initial coding framework was then developed based on the study objectives and the main dimensions of the interview guide, while remaining open to the addition of emerging codes. Codes were progressively grouped into categories, then into themes and sub-themes.

Independent double coding was carried out by MP and SY on 48 interviews. The coding was then compared, and discrepancies were discussed until consensus was reached. The analysis was conducted iteratively, through regular discussions among team members to refine themes, verify their internal consistency, and ensure that interpretations remained grounded in the data. Particular attention was paid to changes in perceptions between T1 and T2, factors promoting or hindering engagement in the program, and the respective contributions of connected devices, the interdisciplinary team, APs, and family caregivers.

Mixed data integration

A longitudinal matrix was built for each participant to relate the qualitative data collected at T1 and T2 to step count trajectory, achievement of individualized goals, and changes in LFI. This matrix helped better interpret the variations observed through the quantitative data (daily steps and LFI changes). This integration aimed to better understand how and why the observed changes occurred within the context of the TAC-Liver graft program.

RESULTS

Quantitative results

Sample characteristics

The majority of the 24 participants were male (n = 16/24; 66.7%). Participants' age ranged from 38 to 69 years, with a mean age of 58.6 years (standard deviation = 7.3) and a median age of 60.5 years, corresponding to a relatively older adult population, consistent with the usual profile of liver transplant recipients (see Table 1).

Table 1
Baseline characteristics of the study sample (N = 24)

Characteristic	**Mean (SD)**
Age (years)	58.6 (7.3)
Characteristic	**N (%)**
Sex	
Female	8 (33.3%)
Male	16 (66.7%)
Education level	
Elementary school	1 (4.2%)
High school diploma	12 (50%)
College diploma	8 (33.3%)
University degree	3 (12.5%)
Distance from residence to the transplant center	
Less than 20 km	4 (17%)
20 to 50 km	4 (17%)
50 to 100 km	5 (21%)
100 to 200 km	3 (12.5%)
200 to 500 km	7 (29%)
More than 500 km	1 (4.2%)

Baseline clinical characteristics of the study participants are presented in Table 2.

[Insert Table 2 here]

Table 2
Baseline clinical characteristics of the study sample (N = 24)

Primary Diagnosis	**N (%)**
MASH cirrhosis	5 (21%)
Alcohol-related cirrhosis	5 (21%)
PBC	3 (12.5%)
HCC	3 (12.5%)
Alcohol-related cirrhosis + HCC	3 (12.5%)
PSC	2 (8.3%)
MASH cirrhosis + HCC	1 (4.2%)
HBV cirrhosis	1 (4.2%)
Graft dysfunction	1 (4.2%)

The two main diagnoses were MASH cirrhosis and alcohol-related cirrhosis, each accounting for 5 participants (20.8%), followed by PBC, HCC, and alcohol-related cirrhosis + HCC, each present in 3 participants (12.5%).

Physical activity

Figure 3 shows daily walking activity and the trajectory class assigned to each of the 24 study participants.

We then applied the proposed three-class classification to the 24 participants:

- Class 1 (decrease, n = 1; 4.2%) grouped participants showing a marked decline in daily walking activity, with a predicted decrease of 86.5% in step count between the start and end of follow-up.
- Class 2 (stable, n = 17; 70.8%) was the largest group and included the majority of participants whose step count remained relatively stable; the group trend showed that these patients did not reduce their steps by more than 25.6% over the course of follow-up.
- Class 3 (increase, n = 6; 25.0%) grouped participants showing an increase in walking activity, and the group trend showed that this increase could reach 225.7% in step count between the start and end of follow-up.

The statistical characteristics of the three identified trajectory classes are summarized in Table 3.

Table 3
Descriptive statistics of daily steps and follow-up duration by trajectory class

Trajectory Class	N (%)	Mean Follow-up Days (SD)	Estimated Change (%)
Class 1 - Decrease	1 (4.2%)	160	-86.5%
Class 2 - Stable	17 (70.8%)	123.1 (99.8)	-25.6%
Class 3 - Increase	6 (25.0%)	188.8 (126.5)	+ 225.7%

Physical activity of the studied subsample

Among the 24 participants with both quantitative and qualitative data, follow-up duration ranged from 17 to 370 days (mean = 141 days, SD = 106.1). Most participants belonged to the "stable" activity class (n = 17; 70.8%), followed by the "increase" class (n = 6; 25.0%) and the "decrease" class (n = 1; 4.2%) (see Fig. 3).

On average, participants met their daily step goal on 74.5% of observed days (SD = 26.8%), although goal achievement varied widely between individuals, ranging from 0% to 100% (Appendix 2). The evolution of the 7-day rolling percentage of daily step-goal achievement over the observation period is shown in Fig. 4.

Liver Frailty Index

At enrollment, the mean LFI was 3.64 (SD = 0.42; n = 23), compared with 3.54 (SD = 0.56; n = 23) at the three-month follow-up, representing a mean decrease of 0.10 points over three months. Both mean values remained within the pre-frail range. Among the 23 participants with both LFI measurements, the large majority improved between T0 and T2 (n = 15; 65.2%), while 7 participants (30.4%) worsened and one remained unchanged (4.3%); note that among the 24 participants, one had missing LFI data.

Table 4 presents the change in physical frailty as measured by the Liver Frailty Index among the 23 participants between enrollment (T0) and the three-month follow-up (T2).

Table 4
Change of the Liver Frailty Index between T0 and T2

Liver Frailty Index (LFI)	Mean (SD)
T0, mean (SD) [N = 23]	3.64 (0.42)
T2, mean (SD) [N = 23]	3.54 (0.56)
Change T0 to T2, n(%) [N = 23]	N (%)
Decrease (LFI improved)	15 (65.2%)
Same	1 (4.3%)
Increase (LFI worsened)	7 (30.4%)

Cross-tabulation of step count with LFI

Cross-tabulating step trajectories with LFI changes identified five profiles among the six theoretically possible combinations in the 23 participants with complete data (Table 5). No participant showed both a decrease in step count and a worsening LFI simultaneously. The participant with missing LFI data was not included in this cross-tabulation analysis.

Table 5
Different patient profiles

Increase in steps	**Favorable LFI / improvement or stability**	**Unfavorable LFI / worsening**
	Profile 1: capacity and action converge **N = 3 (13%)** **TAC_P_020, 026, 034**	**Profile 2: the patient stays active despite clinical decline** **N = 2 (8.7%)** **TAC_P_ 021, 049**
Stable steps	Profile 3: LFI improvement without increased steps N = 12 (52.2%) TAC_P_028, 032, 035, 037, 039, 042, 043, 044, 045, 047, 048, 051	Profile 4: frailty and activity stabilize together N = 5 (21.7%) TAC_P_011, 033, 036, 052, 053
Decrease in steps	Profile 5: LFI improvement with decreased steps N = 1 (4.3%) TAC_P_031	Profile 6: frailty and activity both deteriorate N = 0 (0%)
Note: TAC_P_012 is missing LFI data.		

A Summary of the quantitative data is proposed in Table 6.

Table 6
Summary of quantitative results

Indicator	Distribution			
Step trajectory	Stabilization	Increase	Decrease	
	17/24 (71%) ·	6/24 (25%) ·	1/24 (4%)	
Goal achievement ≥ 70%	Yes		No	
	18/24 (75%)		6/24 (25%)	
LFI change	Improvement	Worsening	Stabilization	No data
	15/23 (65.2%)	7/23 (30.4%)	1/23 (4.3%)	1

Cross-referencing qualitative data to explain quantitative data

To put the quantitative data into perspective alongside the qualitative data, a table maps the data for each of the 24 people participating in the study (see Appendix 3). This integration allows for a better interpretation of step trajectories and LFI changes.

Profile analysis

Profile 1. This profile, the most favorable on both fronts, does not rely on a single combination of factors: for TAC_P_020, the nurse is the main point of contact with the interdisciplinary team, while the family caregiver plays a very substantial role (monitoring ascites, reminding about weigh-ins, daily encouragement to walk) and the AP helps put goals into perspective based on clinical status. For TAC_P_026, conversely, the AP is considered of little use and redundant with nursing follow-up, the kinesiologist was met only once, and it is mainly the nutritionist, available by phone, and the nurse, who closely monitors blood pressure, who structure the follow-up. This contrast suggests that joint improvement in both indicators can be achieved through different combinations of support, without any single factor being essential.

Profile 2. This profile illustrates that an increase in step count alone does not guarantee functional improvement. For TAC_P_034, interdisciplinary follow-up, well documented at T1 (nutritional advice to correct low hemoglobin), becomes completely absent at T2, where only AP support is reported. For TAC_P_021, the contribution of the nutritionist and kinesiologist remains poorly specified, with the physician intervening only through occasional data review, and the peer supporter is considered secondary. For TAC_P_049, despite substantial support (monthly calls from the kinesiologist, regular nutritional advice), the worsening LFI is explained by major functional constraints (three fractured vertebrae, use of a walker) and by an explicit financial barrier preventing the purchase of recommended protein-rich foods. This profile suggests that an increase in steps can coexist with persistent clinical frailty when interdisciplinary follow-up is discontinuous, non-specific, or insufficient considering the patient's clinical and socioeconomic constraints.

Profile 3. This is the most common profile, comprising half the sample. It stands out for particularly rich and individualized engagement from the interdisciplinary team, with the kinesiologist and nutritionist intervening jointly for most patients: exercise prescription and adjustment (TAC_P_032, 039, 043), nutritional plans targeting protein intake or sodium restriction (TAC_P_039, 044, 047, 048), or adaptation to comorbidities such as diabetes (TAC_P_037). Even in the presence of notable clinical constraints (leg and shoulder pain for TAC_P_035, diabetes for TAC_P_037, hospitalization for TAC_P_039), the team remains engaged and the LFI improves. Connected devices are generally viewed positively here, although their perceived value varies: while most patients in this profile describe them as providing structure. One participant, TAC_P_051, was an exception, considering the devices "too basic" compared with their own smartwatch, although this did not prevent an improvement in their LFI, which was driven more by the explanations received from the team about the importance of protein. This profile reinforces the idea that continuity and richness of interdisciplinary follow-up, more than step trajectory alone or technology adherence, are associated with a favorable functional outcome.

Profile 4. This profile splits into two subgroups. On one hand, for TAC_P_011 and TAC_P_053, the interdisciplinary team remains engaged and responsive. Moreover, for TAC_P_053, collaboration between the kinesiologist and nutritionist, followed by coordination with the internal medicine team during a hospitalization, illustrates sustained support despite the worsening, which is explained by disease progression or an acute clinical event rather than a lack of follow-up. On the other hand, for TAC_P_033, TAC_P_036, and TAC_P_052, the worsening coincides with a noticeable discontinuity in follow-up: the kinesiologist met only once for TAC_P_033, a prolonged absence of the nutritionist for TAC_P_052 (explicitly generating anxiety in the patient), and less detailed professional contributions reported at T2 for TAC_P_036. This profile suggests that LFI worsening, in a context of stable step count, must be interpreted taking into account the actual continuity of interdisciplinary support, and not simply as a reflection of an inevitable clinical course.

Profile 5. The only patient with a decreasing step count, TAC_P_031, shows an improved LFI, an apparent paradox explained by a prolonged malfunction of the connected watch (about ten days) rather than genuine disengagement: the dietitian continues to contact him about his weight, the nurse provides regular follow-up, and physicians review his data, although the kinesiologist has less information due to the lack of step data. The absence of patients in this "doubly unfavorable" profile is an encouraging finding, although it should be interpreted with caution given the small sample size.

Analysis of the contribution of each component of the intervention

The role of the interdisciplinary team. Interview analysis reveals that, across all trajectories, the interdisciplinary team is the resource most consistently mentioned by participants, more frequently than the other components of the intervention. The nutritionist or dietitian is mentioned by 23 of the 24 participants (96%), mainly for individualized advice on protein intake, sodium restriction, or adaptation to a specific condition such as diabetes, anemia, or ascites. The kinesiologist is mentioned by 20

participants (83%), with a central role in prescribing and adjusting exercises, although the reported frequency of contact varies considerably from patient to patient, with some having met them only once during follow-up (n = 2; 8%). The nurse is identified by 16 participants (67%) as a responsive point of contact, particularly in the case of missing or abnormal data, while the physician is mentioned more occasionally by 12 participants (50%), mainly to validate clinical progress or coordinate care during an acute episode.

Unlike connected devices, the AP, and the family caregiver, whose contribution varied markedly depending on the step trajectory profile, the interdisciplinary team stands out for its across-the-board presence, reported among participants with increasing, stable, and decreasing trajectories alike. Its role therefore consists not so much in directly increasing physical activity as in individualizing goals and ensuring the safety of overall clinical follow-up. The mechanism of prompt contact in the event of a lack of walking or abnormal data, initially identified in only one participant, is in fact documented in at least 10 of the 24 participants (42%), a practice that is already widespread within the program, rather than an isolated case.

Examination of the seven participants who showed a worsening LFI reveals two distinct profiles. For three of them (43%), the team remains engaged and responsive despite the worsening, which coincides with an acute clinical event such as hospitalization or decompensation. For the other four (57%), the worsening occurs alongside a noticeable discontinuity of interdisciplinary follow-up: reduced contact with the kinesiologist, prolonged absence of the nutritionist, or a loss of detail regarding professional contributions reported between T1 and T2. One participant also reports an explicit financial barrier to adherence to nutritional recommendations, with the suggested protein-rich foods deemed difficult to obtain, a socioeconomic vulnerability factor that adds to the clinical and technical constraints already identified.

Use of connected devices. At T1, most participants perceived them as simple, enjoyable and motivating (n = 13; 54%), and expressed very little technological apprehension (n = 23; 96%). This largely favorable initial reception facilitated adoption of the devices. Between T1 and T2, this perception evolved: from an appreciation centered on novelty and ease of use, it shifted toward a more clinical recognition of the usefulness of connected devices. At T2, they were increasingly described as tools for safety and continuity of follow-up, with automatic transmission of data to the hospital team perceived as a way to reduce unnecessary trips and provide peace of mind. Family caregivers also described a tangible reduction in their mental burden associated with the use of connected devices and the CareSimple® application, particularly through appointment reminders, automatic data transmission, and closer communication with the care team. These features helped reduce stress, feelings of isolation, and the sense of having to bear sole responsibility for follow-up. Connected devices came to serve three complementary functions: clinical monitoring, structuring daily routines, and visualizing changes in health status.

This positive perception remained, however, tempered by persistent technical irritants at T2 (n = 12; 50%), which were spread across synchronization issues (n = 5), battery issues (n = 3), wristband or screen size (n = 3), and the absence of certain desired features (n = 5). Despite these limitations, overall satisfaction remained very favorable: the large majority of participants (n = 20; 83%) described connected devices as having moved from new and motivating tools to clinically useful, reassuring tools fully integrated into their follow-up.

The connected devices' positive contribution to motivation and self-monitoring is consistent across most profiles, but their ability to faithfully capture actual activity varies considerably depending on the patient's mobility profile (walker use, stationary bike, workshop-based activities), and their effect on the LFI always seems to operate in interaction with interdisciplinary follow-up rather than independently. The cases showing the greatest divergence between steps and LFI (profiles 2 and 5) are precisely those where a technical problem or a mismatch between the device and the patient's physical condition is explicitly documented.

The role of accompanying patients. APs provide a source of moral support and reassurance: their experience of transplantation gives their advice particular credibility, helping patients better understand the pre-transplant journey, envision life after transplantation, and make sense of the efforts required. They support the continuity of engagement already established. For those whose step count improved, they reinforce motivation to keep up their efforts, complementing the individualized goals set by the interdisciplinary team. For patients whose activity decreased, their effect on physical activity itself appears more limited when the decline has a clinical origin (fatigue, pain, ascites, shortness of breath, hospitalizations), but they retain an important function of listening and emotional support, distinct from any direct effect on walking.

Their perceived usefulness also grows over time: at T1, 83% of participants (n = 20) considered them a component complementary to the clinical team, versus 17% (n = 4) who viewed them as of little use or redundant; at T2, this reservation persisted in only 4% of participants (n = 1). APs therefore appear as a cross-cutting component of the TAC-Liver graft program, capable of supporting favorable trajectories while offering emotional support to patients whose physical activity declines for clinical reasons. It should be noted that one participant did not benefit from this support during the first month, due to the temporary absence of their AP.

Unlike the interdisciplinary team, whose discontinuity appears associated with certain unfavorable LFI trajectories (profile 4), and connected devices, whose technical mismatch directly explains certain discrepancies between steps and LFI (profiles 2 and 5), the role of the AP appears more uniformly positioned on a psychological and relational level across all five profiles, independent of the quantitative or functional trajectory observed. Its intensity certainly varies from patient to patient (sometimes central, sometimes considered redundant, or sometimes emerging), but this variation does not appear to be systematically correlated with LFI change, unlike what is observed for the interdisciplinary team. The AP appears to act mainly as a factor of emotional support and psychological preparation for

transplantation, complementary to but distinct from the clinical (interdisciplinary team) and technical (connected devices) factors, which appear to be more directly associated with the functional trajectories observed.

The qualitative data also suggested a possible compensatory role of APs: in several participants for whom family caregiver involvement was limited or not documented, APs were particularly valued for reassurance, emotional support, and sharing their experience. This observation remains speculative, however, as family caregiver involvement was not systematically documented or compared across participants.

The contribution of family caregivers. Family caregivers contribute to changes in step count, mainly by supporting patients' engagement in the routines proposed by the program. Eleven participants (46%) explicitly mention the role of their family caregiver, and nine of them (38%) were in fact accompanied by their caregiver during the interview conducted at T2. In maintenance and improvement trajectories, family caregivers provide concrete, day-to-day support: encouragement to walk, maintaining established routines, and sometimes help interpreting data or symptoms reported through the platform, all contributions that promote continuity of engagement, complementing connected devices, clinical follow-up, and peer support.

Across the five profiles, the family caregiver remains the least consistently documented factor, with a reported presence in about half the patients in each profile, consistent with the overall proportion already established for the entire sample (46%). Unlike the interdisciplinary team, whose discontinuity coincides with LFI worsening in profile 4, the presence or absence of a family caregiver does not on its own appear to be a clearly differentiating factor between favorable and unfavorable profiles: some patients with improved LFI do without one (profile 3), while some patients with worsened LFI benefit from one (profile 4, TAC_P_033). The family caregiver seems instead to play a complementary and often invisible support role (logistical, emotional, sometimes interpretive with respect to data).

DISCUSSION

Main findings

This preliminary longitudinal mixed-methods study evaluates the TAC-Liver graft program, a connected prehabilitation model integrating connected devices with a monitoring application, an interdisciplinary team, and APs for patients awaiting liver transplantation. To our knowledge, this is the first study of this type to be published. The results first show that the LFI (clinical functional status) provides a better reflection of the program's overall benefit than step count alone. A direct correlation between the two indicators might have been expected, but this was not the case.

To better understand this discordance, patients were classified into five profiles crossing step trajectory with LFI change. This approach is itself an important contribution to the study, as it reveals that discordance or convergence between the two indicators is clinical information in its own right. Half the

sample (n = 12; 50%) showed stable step count accompanied by improved LFI, confirming that a "stable" step trajectory most often masks genuine behavioral engagement (new habits, dietary discipline, physical exercise) that is not captured by steps alone. Conversely, among the five participants whose step count increased and whose LFI data was complete, two improved their LFI, one remained stable, and two worsened. No participant showed both a decrease in steps and a worsening LFI simultaneously. The profile-based approach also highlights a systems theory principle of equifinality: the two participants who both increased their steps and improved their LFI achieved this through different combinations of support, relying more on the family caregiver and AP for one, and on the nutritionist and nurse for the other. Among the five participants whose LFI worsened despite stable steps, this change coincided with an acute clinical event in two participants and with less reported interdisciplinary follow-up in three participants (60%). This clinical distinction is made possible through this profile-based analysis and the use of qualitative data. Patients with the heaviest physical constraints (walker use, ascites, fractured vertebrae) may also show the strongest qualitative motivation, illustrating how essential the cross-referencing of quantitative and qualitative data is for an accurate interpretation of individual trajectories.

The results also show that the factors promoting better clinical outcomes are of several kinds, with no single combination standing out. The very context of preparing for transplantation remains the most consistent motivational driver, as this period is conducive to triggering determination to give oneself a chance to survive the disease. The contribution of connected devices and the CareSimple® platform allow data to be visualized as graphs, which helps patients track their efforts and may give them a sense of regaining control over their disease, pride in themselves and toward the clinical team, and may allow them to achieve small day-to-day challenges. The feeling of being monitored daily is a second important factor: platform and professional reminders, as well as the possibility of prompt contact with the team in the event of inactivity or suspicious data (a practice documented in at least 10 of the 24 patients (42%)), keep the patient from feeling abandoned and reassure them in pursuing their goals. Finally, automated data transfer avoids manual notetaking, a source of errors and omissions.

Among the identifiable limiting factors to physical activity, the first are factors related to the patient's clinical status (ascites, shortness of breath, fatigue, pain, fractures, hospitalizations), which prevent them from achieving their steps goals. Winter-related environmental factors, such as cold and ice limiting outings, were also reported, as were technical factors (poorly fitting wristband, suboptimal synchronization, battery issues) and an emotional factor related to waiting and uncertainty about receiving the transplant. The profile-based analysis highlights two additional limiting factors that were previously less visible in an overall reading of the results. First, reduced or less clearly documented interdisciplinary follow-up (a kinesiologist met only once, prolonged absence of the nutritionist, or less detailed reporting of professional contacts at T2 than at T1) coincided with LFI worsening in 4 of the 7 affected patients (57%), suggesting a potentially modifiable factor distinct from disease progression alone. Second, an explicit financial barrier to adherence to nutritional recommendations was reported by one participant (4%), who described difficulty obtaining the recommended protein-rich foods. Although this was an isolated observation, it highlights a potential socioeconomic barrier that may warrant further exploration in a larger sample.

Finally, the results confirm four sources of support, whose respective contributions become clearer considering the profiles. Connected devices (CDs) are almost always perceived positively for monitoring and reminders, although their effect on intrinsic motivation may have its limits, as shown by one patient who considered them "too basic" and unhelpful for habit change, a marginal case, but one whose LFI nevertheless improved, illustrating that functional benefit can occur independently of technology adherence. In patients with reduced mobility or engaging in non-ambulatory activities, CDs can even become counterproductive, as in one patient for whom the watch, ill-suited to walker use, became explicitly demoralizing rather than motivating, a profile (increased steps without LFI improvement) where the technical mismatch of the device is directly documented. The second source of support, the interdisciplinary team, has access to data from the CDs and co-builds the patient's exercise plan with them, adjusting it according to clinical status. The profile-based analysis indicates that it is precisely the continuity of this support, more than the presence of CDs or the AP, that most clearly distinguishes favorable from unfavorable LFI profiles. As for APs, they occupy an important place valued by several participants acting mainly on an emotional and experiential level rather than on walking behavior itself; for others this role remains secondary or not very engaging, most often due to a lack of real contact or rapport. This variability, unlike that of the interdisciplinary team, is not differentially associated with any particular steps/LFI profile. Finally, the role of family caregivers, documented in about half of patients (46%), is very concrete and engaged when reported: family members provide direct support in achieving steps, participate in clinical monitoring, and lighten the mental load associated with daily follow-up. Nonetheless their presence or absence does not systematically differentiate favorable from unfavorable profiles.

Stabilization of steps

An important finding of this research is that a majority of patients stabilized their step count rather than increasing it. This result might seem disappointing, but in light of the literature on the natural evolution of physical activity in liver transplant candidates, it takes on an entirely different meaning. Indeed, a recent prospective cohort documents a trend toward a progressive decline in physical activity among patients awaiting transplantation, linked to the progression of liver disease itself [43]. Another study of patients on the liver transplant waiting list shows physical activity levels markedly lower than the general population, with average counts on the order of 3,000 to 3,500 steps per day, comparable to those observed in patients with advanced heart, lung, or kidney failure [44]. A threshold of 5,000 steps per day has also been proposed as a marker of clinical stability and lower risk of decompensation in patients living with cirrhosis [44]. Some of the patients studied fall precisely around this threshold, suggesting that their trajectory, although labeled "stabilization," actually corresponds to maintaining a zone of clinical safety rather than neutral stagnation. In this context, stabilization of steps does not represent a program failure but rather a clinically meaningful result, as the program may help slow an otherwise expected downward slope.

Measurement bias

Results from the connected devices show an almost systematic capture bias (watch removed, non-ambulatory activities poorly detected, technical malfunctions). This finding strongly converges with the methodological literature on the use of connected devices in hepatology. Duarte-Rojo and colleagues explicitly highlighted the gap between clinically assessed physical performance and objectively measured physical activity in liver transplant candidates, a gap partly attributed to the technical limitations of motion sensors in a population whose gait is often slow, unstable, or assisted (walker, cane) [45].

This phenomenon is particularly well illustrated by the sample's patients using a walker or engaging in non-ambulatory activities such as stationary cycling: the literature confirms that pedometers and smartwatches systematically underestimate effort in this type of profile, a bias that is not specific to the device used here but inherent to step-counting technology in general [45].

Another documented and relevant phenomenon concerns the "novelty effect." A feasibility study of the EL-FIT application reports initially high performance among several participants, followed by a decline over the following weeks, as enthusiasm for the new device fades [21]. This phenomenon could explain part of the stabilization or slight decrease trajectories observed between T1 and T2 in certain patients, independent of any actual clinical change.

Change in LFI

The recent literature supports the idea, already established in our analysis, that the LFI is a more stable and clinically more informative indicator than raw step trajectory. The LFI was developed and validated specifically for the cirrhotic population by the Functional Assessment in Liver Transplantation consortium led by Lai and colleagues [10, 46]. It predicts waitlist mortality as well as the risk of acute decompensation. A recent multicenter study even established clinically significant thresholds. An improvement in LFI of as little as 0.1 point over three months is associated with a measurable 6% reduction in waitlist mortality risk [47]. In our study, the mean LFI decreased by 0.10 points, from 3.64 to 3.54, although both mean values remained within the pre-frail range. Given the small sample size and the preliminary nature of the present analysis, this observed decrease should therefore be interpreted as a potentially favorable functional change rather than evidence of a clinically significant intervention effect.

This reference framework helps better understand why a majority of patients in this study show an improvement in LFI despite stabilization of steps. Unlike step count, the LFI incorporates grip strength, chair-stand ability, and balance, and balance; activities that are not captured by the watch (resistance exercises, cycling, sessions with the kinesiologist) can directly improve these dimensions. A randomized trial of a home-based nutritional intervention also showed a significantly greater improvement in LFI in the intervention group than in the control group (0.8 versus 0.4 points) [48], reinforcing the idea that structured interventions, even without a visible effect on steps, can produce a real and measurable functional benefit.

Contribution of digital tools

The role of connected devices as influencers of motivation, accountability, and self-monitoring, as widely described in the interviews, is consistent with the mechanisms reported in feasibility studies of applications dedicated to liver prehabilitation, notably the EL-FIT application developed specifically for liver transplant candidates [21]. This work shows that a notable share of users significantly increases their physical activity thanks to data visualization and community or team follow-up features, particularly among the most sedentary patients at baseline, which echoes the profiles of several participants in this study (TAC_P_034, TAC_P_048).

On the broader evidence front, Jetten et al. [49] concluded that prehabilitation in liver transplant candidates appears feasible and safe and reported improvements in aerobic capacity, 6-minute walking distance, handgrip strength, LFI, and quality of life. More recently, a systematic review and meta-analysis by Abow-Mohamed et al. [50] confirmed the feasibility and safety of prehabilitation and found significant improvements in several measures of physical fitness, including VO_2, the 6-minute walk test, LFI, and the Short Physical Performance Battery. Jetten et al. [49] also reported substantial variation in adherence according to the degree of supervision, ranging from 38% to 90% in unsupervised programs compared with 94% or higher in supervised programs. However, evidence regarding post-transplant clinical outcomes remains limited: the recent meta-analysis found no significant differences in post-transplant mortality, hospital length of stay, or intensive care unit length of stay between intervention and control groups [50]. The TAC-Liver graft program, with close interdisciplinary follow-up and automated reminders, resembles a supervised model, which may partly explain the high level of daily goal achievement observed in this study (75% of participants achieved their daily step goal on at least 70% of observed days).

Contribution of the interdisciplinary team

For several patients, it is explicitly the interdisciplinary team (kinesiologist, nutritionist, nurse), and not the connected devices themselves, that was identified as the primary source of motivation or behavior change. Connected devices make behaviors and health indicators visible, but the professionals give clinical meaning to this data, translate it into concrete recommendations, and help participants understand why the requested changes matter. One patient illustrates this by attributing the resumption of walking and exercise to explanations received about the importance of protein and muscle mass before transplantation, while explicitly stating that connected devices do not really support their habit changes. For another participant, change instead relies on the link between data monitoring and understanding the importance of good physical condition before and after transplantation; clearly explained exercises and answers to nutritional questions reinforce this process. One participant also describes a collective contribution from the kinesiologist, dietitian, and AP, which leads them to pay closer attention to their diet, walking, and exercise. These findings thus suggest that technological measurement alone does not produce change: it becomes more motivating when accompanied by explanations, advice, and human follow-up.

The interdisciplinary team also plays an essential role in personalizing, progressing, and ensuring the safety of goals. This was illustrated in two patients, for whom the kinesiologist adjusted the daily step

target (moving from 4,000 to 5,000 steps; setting a daily minimum) based on the patient's progress. This function of adjusting a realistic and safe goal given ascites, fatigue, or pain is assumed neither by the connected devices, nor by the AP (who has no access to clinical data from the connected devices), nor by the family caregiver, but rather by the team's professionals. This responsiveness has also been highlighted in a clinical study in which LFI results allow professionals to adapt individualized goals [51, 52]. The prompt-contact mechanism in the event of inactivity reinforces this key adherence factor. Indeed, the nurse interprets the signal generated by the platform and can respond quickly with a clinical intervention.

This central role of the interdisciplinary team is consistent with the literature on prehabilitation in liver transplantation, which favors an intervention combining physical exercise, nutritional advice, and psychological support rather than a stand-alone intervention [14]. Prehabilitation clinic models described in the literature explicitly rely on a coordinated multidisciplinary team, including an exercise professional (kinesiologist, physiotherapist) and a dietitian, overseen by an advanced care provider [53]. Connected devices are generally positioned there as support tools for the team rather than as stand-alone interventions, as underscored by patients, who clearly distinguish the team's clinical contribution from that of the technology itself.

Contribution of accompanying patients

The heterogeneity observed in the APs' contribution echoes a recurring finding in the literature on peer mentoring programs in the transplantation context. These programs are fairly consistently associated with psychosocial benefits: reduced isolation, a sense of being understood, transmission of lived experience, and strengthened self-efficacy [54]. However, its direct contribution to specific behavioral or functional outcomes, such as physical activity, remains less clearly established.

In most cases, the AP is described qualitatively as reassuring and a source of valuable lived experience, without patients themselves reporting a direct, measurable effect on walking. However, this may be explained by the fact that APs do not have access to patients' dashboards. This suggests that the peers act mainly through indirect mechanisms such as reducing anxiety and psychological preparation for transplantation, which are likely to support overall motivation without translating into an immediate, quantifiable change in walking behavior. Accompanying patients appear to act as relays or amplifiers to the clinical oversight already structured by the interdisciplinary team. Our individual-level analysis further raises the possibility that this psychosocial role may become particularly salient when family caregiver support is limited or absent, suggesting a potential compensatory function of AP. This hypothesis should be examined explicitly in future studies.

Contribution of family caregivers

Although the role of the family caregiver was not documented systematically, when mentioned, their contribution is described as decisive (monitoring, reminders, direct support for walking). This asymmetry

corresponds to a recurring blind spot identified in the liver transplantation literature. Family caregivers play a central logistical and emotional role throughout the transplant journey but remain an understudied population, often not formally integrated into follow-up protocols [30, 55].

The literature also documents a substantial burden among family caregivers of liver transplant candidates, including psychological distress, reduced social functioning, and unmet needs related to caregiving and interactions with healthcare professionals [20, 30, 56]. This finding provides context for the explicit request from the spouse of TAC_P_020 to be more closely included in communications with the clinical team. Similar needs for caregiver preparation, support, and greater involvement in care have been reported throughout the liver transplantation journey [20, 30, 56].

Contribution of this integrated intervention

The originality of this integrated intervention, which includes connected devices, a monitoring application, an interdisciplinary team, and peer partners, has not yet been the subject of publication. This also limits the availability of direct comparators in the literature. However, it appears that this combination allows each of these sub-components to be potentiated. Connected devices and the digital platform need "human" oversight to reach their full potential. Even though the role of accompanying patients in fostering motivation is not demonstrated, they act in concert with the clinical team and thus contribute to this oversight. They also influence emotions, making patients less anxious and therefore more receptive to engage in their own health.

Implications for practice

Given the preliminary nature of these findings, definitive recommendations would be premature. However, the results highlight several potential areas for consideration in the ongoing development of the TAC-Liver graft program, including the integration of physical activity, functional frailty, and qualitative information to assess patient trajectories, individualized physical activity goals, continuity of interdisciplinary follow-up, and adaptation of monitoring tools to patients' functional status. These potential implications should be reassessed as additional participants and longer-term follow-up data become available.

Strengths and limitations

This study has several strengths. First, its mixed-methods, longitudinal design: the systematic cross-referencing of quantitative data (steps, LFI) and qualitative data (T1/T2 interviews) at the individual patient level is rare in the literature on liver prehabilitation, where most studies are limited to either aggregated objective measures or isolated qualitative data. This approach allows for a nuanced interpretation that statistics alone could not offer. This integration also enabled the identification of five profiles crossing step trajectory with LFI change, which is a methodological contribution in itself. Rather than mere statistical noise, the discordance between these two indicators becomes interpretable clinical information, revealing a principle of equifinality (patients reaching an equally favorable outcome through very different combinations of support). Moreover this is an actionable distinction, among less favorable

trajectories, between worsening linked to an acute clinical event and worsening coinciding with a discontinuity in interdisciplinary follow-up. This classification offers a reproducible framework for future studies on connected prehabilitation. The second strength is the clinical granularity at the level of each patient: it was possible to detail facilitating factors, obstacles, and clinical context individually rather than as a group average, which would have masked atypical situations (e.g., TAC_P_049 with a walker, TAC_P_042 with non-ambulatory activities). The third is transparency regarding measurement bias: circumstances likely to bias step data (watch removed, technical malfunction, activity not captured) are documented patient by patient, a rare level of rigor when most studies report step counts without discussing their individual validity. Another strength is the integration of information on four complementary support components: connected devices, the interdisciplinary team, accompanying patients, and family caregivers. Qualitative rigor was strengthened through independent double coding, consensus discussions, iterative team review, and COREQ-informed reporting. The ecological validity of the study is also a strength, as the evaluation was conducted within the real-world clinical setting of the TAC-Liver graft program rather than under controlled experimental conditions, thereby enhancing the practical relevance of the findings. Finally, integrating patient and family caregiver perspectives in several cases (TAC_P_020, TAC_P_032, and TAC_P_044) provided complementary information and, in some instances, helped clarify or nuance patients' accounts of their experiences.

Reflexivity Statement

The authors occupied different positions in relation to the TAC-Liver graft program and its evaluation. MPP, SY, CV and MJEC were members of the core research team responsible for the evaluation, analysis, and interpretation of the findings. JP, AB, MCB, BV, GJ, and AP were hospital-based professionals who contributed, to varying degrees, to the development, implementation, clinical delivery, or coordination of the TAC-Liver graft program. JTL, LL and CB contributed as patient partners and accompanying patients with lived experience of liver transplantation. Nevertheless, because all authors had some connection to the program or the institution, no fully external perspective was represented. Residual biases, particularly intervention allegiance and social desirability bias, may therefore remain.

FUTURE RESEARCH

In order to establish a causal link, it would be desirable to extend data collection beyond transplantation to assess whether pre-transplant trajectories (steps, LFI) predict functional recovery, medical consultations, length of hospital stay, readmissions, or post-operative complications. In addition, it would be worthwhile to conduct a randomized controlled or quasi-experimental trial to compare the current program (connected devices + interdisciplinary team + peer supporter + family caregiver) with a group receiving standard care, or with arms isolating each component (connected devices alone, connected devices + clinical team, connected devices + peer supporter, full program), in order to determine the specific contribution of each component of the intervention to changes in LFI and clinical outcomes. A

stratified analysis by frailty level, considering baseline LFI (robust/pre-frail/frail), would also help verify whether the facilitators and obstacles identified differ according to degree of frailty.

Regarding possible measurement bias related to the novelty effect, a longitudinal study including several measurement time points (T1, T2, T3, T4…) would make it possible to track the evolution of steps over more than two time points to distinguish genuine motivational decline from a simple return to baseline after the initial novelty of the device wears off.

Regarding family caregivers, a deeper examination of their role through systematic semi-structured interviews would help better characterize their actual contribution to physical activity and their own burden related to the program. In addition, caregiver burden could be assessed using a validated instrument such as the Zarit Burden Interview [57], allowing changes in caregiver burden to be tracked before and after participation in the program and helping determine whether structured support effectively reduces caregiver burden.

It would also be interesting to study the feasibility and the economic cost of implementing such a program on a larger scale by assessing the additional clinical workload (nursing time and time of other health professionals, technical support time) and the costs of the digital platform and connected devices, while also incorporating returns on investment in terms of care use (emergency room visits, consultations with professionals such as physicians, hospitalization, etc.). Finally, a multicenter study reproducing the design at other liver transplant centers, with other technological platforms, to test the generalizability of the findings beyond a single program and a single device (CareSimple®), would be worth conducting.

Conclusion

This preliminary longitudinal mixed-methods study is the first to evaluate an integrated pre-habilitation program integrating connected devices, a mobile application, an interdisciplinary team, and accompanying patients for patients listed for liver transplantation. Through the cross-referencing of quantitative data (step trajectory, goal achievement) and qualitative data (facilitating and limiting factors, contribution of connected devices, the clinical team, the peer supporter, and family caregivers), the results show that most patients present a stabilization, rather than an increase, in their daily step count, while an improvement in the Liver Frailty Index is observed in most of them. This apparent paradox, far from reflecting a program failure, is interpreted in light of the natural trajectory of functional decline usually documented in patients awaiting liver transplantation. The program appears to help maintain a level of physical activity, which is a clinically significant result.

The qualitative analysis also reveals an almost systematic capture bias in connected devices, particularly marked among patients with reduced mobility or engaging in non-ambulatory activities, which calls for caution in interpreting any step trajectory in isolation from its clinical context. The respective contribution of the four support levers studied (connected devices, interdisciplinary team, AP, and family caregiver) proves complementary: connected devices mainly support self-monitoring and

daily accountability, the interdisciplinary team helps set lifestyle goals and put in place strategies to achieve them, the PA acts on psychological state and experiential reassurance while maintaining motivation to take steps. Finally, when present the family caregiver appears as a decisive factor in maintaining a walking routine.

These findings, consistent with the emerging literature on prehabilitation in liver transplantation, argue for a multidimensional evaluation of these programs, combining validated functional indicators and qualitative data, rather than a reading centered on step count alone. They also call for more formal recognition of the role of family caregivers in the design and follow-up of these interventions. Given the small sample size and the absence of a control group, these results should be considered exploratory. Larger comparative studies, including post-transplant follow-up, will be needed to establish the causal contribution of each of these components to long-term clinical outcomes.

Abbreviations

AP
Accompanying patient
AIC
Akaike information criterion
BIC
Bayesian information criterion
CDs
Connected devices
CHUM
Centre hospitalier de l'Université de Montréal
COREQ
Consolidated Criteria for Reporting Qualitative Research
GBTM
Group-based trajectory modeling
LFI
Liver Frailty Index
TAC-Liver graft
Transplant Action Connected program in liver transplantation

Declarations

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Authors' contributions

Shuaiqi Yuan contributed to the study methodology, data curation, quantitative and qualitative analyses, integration of the mixed-methods findings, visualization, interpretation of the results, and drafting of the original manuscript. Marie-Pascale Pomey contributed to the conceptualization and design of the study, methodology, supervision, interpretation of the findings, and critical revision of the manuscript. Catherine Vincent and Manuel José Escalona Castillo contributed to the evaluation of the program, interpretation of the findings, and critical review of the manuscript. Jessie Perron, Angèle Barry, Marie-Christine Bertrand, Béatrice Vaillancourt, Gabrielle Jutras, and Alfons Pomp contributed to the development, implementation, clinical delivery, and/or coordination of the TAC-Liver graft program and to the interpretation of the findings. Johanne Tetrault Lassonde, Louise Laviolette, and Colette Bérubé contributed as patient partners and accompanying patients, bringing lived-experience perspectives to the development and interpretation of the study. Denis Ouellette, Mathieu Gradassi, Geneviève Huard, Chantal Bemeur, and Christopher Rose contributed to the interpretation of the findings and critically reviewed the manuscript. All authors reviewed and approved the final manuscript.

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Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available because they contain sensitive clinical and qualitative information and are subject to institutional and ethical requirements regarding participant confidentiality.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2, 2022)*. The study was approved by the Research Ethics Committee of the Centre hospitalier de l'Université de Montréal (CHUM), Quebec, Canada (project number: 20-5185). All participants received information about the study objectives, potential benefits, and associated risks and provided free and informed written consent before participation.

Consent to Publish declaration

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

1. European Association for the Study of the Liver (2024) EASL Clinical Practice Guidelines on liver transplantation. J Hepatol 81:1040–1086. https://doi.org/10.1016/j.jhep.2024.07.032
2. Lai JC, Sonnenday CJ, Tapper EB, Duarte-Rojo A, Dunn MA, Bernal W et al (2019) Frailty in liver transplantation: An expert opinion statement from the American Society of Transplantation Liver and Intestinal Community of Practice. Am J Transpl Off J Am Soc Transpl Am Soc Transpl Surg 19:1896–1906. https://doi.org/10.1111/ajt.15392
3. Bailey DE, Yao J, Yang Q (2021) Illness Uncertainty in Patients Awaiting Liver Transplant. West J Nurs Res 43:509–516. https://doi.org/10.1177/0193945920952059
4. Dhaliwal A, Williams FR, El-sherif O, Armstrong MJ (2020) Sarcopenia in Liver Transplantation: an Update. Curr Hepatol Rep 19:128–137. https://doi.org/10.1007/s11901-020-00515-z
5. Maharshi S, Sharma BC, Srivastava S (2015) Malnutrition in cirrhosis increases morbidity and mortality. J Gastroenterol Hepatol 30:1507–1513. https://doi.org/10.1111/jgh.12999
6. Merli M, Riggio O, Dally L (1996) Does malnutrition affect survival in cirrhosis? Hepatology 23:1041. https://doi.org/10.1002/hep.510230516
7. Rogal SS, Hansen L, Patel A, Ufere NN, Verma M, Woodrell CD et al (2022) AASLD Practice Guidance: Palliative care and symptom-based management in decompensated cirrhosis. Hepatol Baltim Md 76:819–853. https://doi.org/10.1002/hep.32378
8. Tantai X, Liu Y, Yeo YH, Praktiknjo M, Mauro E, Hamaguchi Y et al (2022) Effect of sarcopenia on survival in patients with cirrhosis: A meta-analysis. J Hepatol 76:588–599. https://doi.org/10.1016/j.jhep.2021.11.006
9. Lai JC, Feng S, Terrault NA, Lizaola B, Hayssen H, Covinsky K (2014) Frailty Predicts Waitlist Mortality in Liver Transplant Candidates. Am J Transpl 14:1870–1879. https://doi.org/10.1111/ajt.12762
10. Lai JC, Covinsky KE, Dodge JL, Boscardin WJ, Segev DL, Roberts JP et al (2017) Development of a novel frailty index to predict mortality in patients with end-stage liver disease. Hepatol Baltim Md 66:564–574. https://doi.org/10.1002/hep.29219
11. Fleurent-Grégoire C, Burgess N, McIsaac DI, Chevalier S, Fiore JF, Carli F et al (2024) Towards a common definition of surgical prehabilitation: a scoping review of randomised trials. BJA Br J Anaesth 133:305–315. https://doi.org/10.1016/j.bja.2024.02.035
12. Lai JC, Dodge JL, Sen S, Covinsky K, Feng S (2016) Functional Decline in Patients with Cirrhosis Awaiting Liver Transplantation: Results from the Functional Assessment in Liver Transplantation (FrAILT) Study. Hepatol Baltim Md 63:574–580. https://doi.org/10.1002/hep.28316
13. Tonon M, Gagliardi R, Zeni N, Piano S (2024) Recompensation of cirrhosis in candidates of transplant: Tips and tricks for delisting. Liver Transpl 30:1181.

https://doi.org/10.1097/LVT.0000000000000409

14. Benmassaoud A, Martel M, Carli F, Geraci O, Daskalopoulou SS, Sebastiani G et al (2024) Prehabilitation in patients awaiting liver transplantation. Transpl Rev 38:100835. https://doi.org/10.1016/j.trre.2024.100835
15. Lai JC, Tandon P, Bernal W, Tapper EB, Ekong U, Dasarathy S et al (2021) Malnutrition, Frailty, and Sarcopenia in Patients With Cirrhosis: 2021 Practice Guidance by the American Association for the Study of Liver Diseases. Hepatol Baltim Md 74:1611–1644. https://doi.org/10.1002/hep.32049
16. Tandon P, Ismond KP, Riess K, Duarte-Rojo A, Al-Judaibi B, Dunn MA et al (2018) Exercise in cirrhosis: Translating evidence and experience to practice. J Hepatol 69:1164–1177. https://doi.org/10.1016/j.jhep.2018.06.017
17. Jamali T, Raasikh T, Bustamante G, Sisson A, Tandon P, Duarte-Rojo A et al (2022) Outcomes of Exercise Interventions in Patients With Advanced Liver Disease: A Systematic Review of Randomized Clinical Trials. Off J Am Coll Gastroenterol ACG 117:1614. https://doi.org/10.14309/ajg.0000000000001883
18. Ney M, Gramlich L, Mathiesen V, Bailey RJ, Haykowsky M, Ma M et al (2017) Patient-Perceived Barriers to Lifestyle Interventions in Cirrhosis. Saudi J Gastroenterol Off J Saudi Gastroenterol Assoc 23:97–104. https://doi.org/10.4103/1319-3767.203357
19. Strauss AT, Brundage J, Sidoti CN, Jain V, Gurakar A, Mohr K et al (2024) Patient perspectives on liver transplant evaluation: A qualitative study. Patient Educ Couns 127:108346. https://doi.org/10.1016/j.pec.2024.108346
20. Miyazaki ET, dos Santos R Jr, Miyazaki MC, Domingos NM, Felicio HC, Rocha MF et al (2010) Patients on the waiting list for liver transplantation: Caregiver burden and stress. Liver Transpl 16:1164–1168. https://doi.org/10.1002/lt.22130
21. Duarte-Rojo A, Bloomer PM, Rogers RJ, Hassan MA, Dunn MA, Tevar AD et al (2021) Introducing EL-FIT (Exercise and Liver FITness): A Smartphone App to Prehabilitate and Monitor Liver Transplant Candidates. Liver Transplant Off Publ Am Assoc Study Liver Dis Int Liver Transplant Soc. 27:502–512. https://doi.org/10.1002/lt.25950
22. Penrice DD, Hara KS, Sordi-Chara B, Kezer C, Schmidt K, Kassmeyer B et al (2024) Design, implementation, and impact of a cirrhosis-specific remote patient monitoring program. Hepatol Commun 8:e0498. https://doi.org/10.1097/HC9.0000000000000498
23. Wu T, Louissaint J (2024) Emerging digital technologies to help patients with cirrhosis. Clin Liver Dis 23:e0209. https://doi.org/10.1097/CLD.0000000000000209
24. Kazankov K, Novelli S, Chatterjee DA, Phillips A, Balaji A, Raja M et al (2023) Evaluation of CirrhoCare® – a digital health solution for home management of individuals with cirrhosis. J Hepatol 78:123–132. https://doi.org/10.1016/j.jhep.2022.08.034
25. Pomey M-P, Flora L, Karazivan P, Dumez V, Lebel P, Vanier M-C et al (2015) Le « Montreal model »: enjeux du partenariat relationnel entre patients et professionnels de la santé. Santé Publique. S.F.S.P.; ;1:41–50. https://doi.org/10.3917/spub.150.0041

26. Fox G, Lalu MM, Sabloff T, Nicholls SG, Smith M, Stacey D et al (2023) Recognizing patient partner contributions to health research: a systematic review of reported practices. Res Involv Engagem 9:80. https://doi.org/10.1186/s40900-023-00488-5
27. Joo JH, Bone L, Forte J, Kirley E, Lynch T, Aboumatar H (2022) The benefits and challenges of established peer support programmes for patients, informal caregivers, and healthcare providers. Fam Pract 39:903–912. https://doi.org/10.1093/fampra/cmac004
28. NHS E Supported self-management: peer support guide [Internet]. NHS Engl. 2023 [cited 2026 Aug 2]. https://www.england.nhs.uk/long-read/peer-support/. Accessed 2 Aug 2026
29. Cooper KM, Colletta A, Hathaway NJ, Liu D, Gonzalez D, Talat A et al (2023) Delayed referral for liver transplant evaluation worsens outcomes in chronic liver disease patients requiring inpatient transplant evaluation. World J Transpl 13:169–182. https://doi.org/10.5500/wjt.v13.i4.169
30. Deng LX, Sharma A, Gedallovich SM, Tandon P, Hansen L, Lai JC (2023) Caregiver Burden in Adult Solid Organ Transplantation. Transplantation 107:1482–1491. https://doi.org/10.1097/TP.0000000000004477
31. Pomey M-P, Roux EL, Nadon N, Perron J, Barry A, Bémeur C et al (2024) Telehealth-Delivered Program and Accompanying Patients to Enhance the Clinical Condition of Patients Throughout a Liver Transplant: Protocol for a Mixed Methods Study. JMIR Res Protoc, vol 13. JMIR Publications Inc., Toronto, Canada, p e54440. https://doi.org/10.2196/54440
32. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W et al (2015) Process evaluation of complex interventions: Medical Research Council guidance. BMJ 350:h1258. https://doi.org/10.1136/bmj.h1258
33. Rollnick S, R.Miller W, C.Butler C (2022) Motivational Interviewing in Health Care: Second Edition: Helping Patients Change Behavior [Internet]. 2nd ed. New York: Guilford Press; [cited 2026 May 20]. https://www.guilford.com/books/Motivational-Interviewing-in-Health-Care/Rollnick-Miller-Butler/9781462550371? Accessed 20 May 2026
34. Kardashian A, Ge J, McCulloch CE, Kappus MR, Dunn MA, Duarte-Rojo A et al (2021) Identifying an Optimal Liver Frailty Index Cutoff to Predict Waitlist Mortality in Liver Transplant Candidates. Hepatol Baltim Md 73:1132–1139. https://doi.org/10.1002/hep.31406
35. Jutras G, Lai JC (2024) The Liver Frailty Index: a model for establishing organ-specific frailty metrics across all solid organ transplantation. Curr Opin Organ Transpl 29:266. https://doi.org/10.1097/MOT.0000000000001157
36. Proust-Lima C, Philipps V, Liquet B (2017) Estimation of Extended Mixed Models Using Latent Classes and Latent Processes: The R Package lcmm. J Stat Softw 78:1–56. https://doi.org/10.18637/jss.v078.i02
37. Proust-Lima C, Philipps V, Diakite A, Liquet B subroutine) AG (Author of hrmsym, subroutine) JB (Author of alnorm. lcmm: Extended Mixed Models Using Latent Classes and Latent Processes [Internet]. 2025 [cited 2026 Sept 3]. https://cran.r-project.org/web/packages/lcmm/index.html. Accessed 3 Sept 2026

38. Box GEP, Cox DR (1964) An Analysis of Transformations. J R Stat Soc Ser B Methodol 26:211–243. https://doi.org/10.1111/j.2517-6161.1964.tb00553.x
39. Nagin DS, Odgers CL (2010) Group-based trajectory modeling in clinical research. Annu Rev Clin Psychol 6:109–138. https://doi.org/10.1146/annurev.clinpsy.121208.131413
40. Tong A, Sainsbury P, Craig J (2007) Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. Int J Qual Health Care 19:349–357. https://doi.org/10.1093/intqhc/mzm042
41. Braun V, Clarke V (2006) Using thematic analysis in psychology. Qual Res Psychol Routledge 3:77–101. https://doi.org/10.1191/1478088706qp063oa
42. Fereday J, Muir-Cochrane E (2006) Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. Int J Qual Methods SAGE Publications Inc 5:80–92. https://doi.org/10.1177/160940690600500107
43. Magyar CTJ, Bühlmann L, Becchetti C, Beekman L, Candinas D, Beldi G et al (2024) Physical activity decreases in patients on the liver transplant waiting list and influences postoperative outcome—a prospective cohort study. HepatoBiliary Surg Nutr AME Publishing Co 13:22940–22240. https://doi.org/10.21037/hbsn-23-399
44. Dunn MA, Kappus MR, Bloomer PM, Duarte-Rojo A, Josbeno DA, Jakicic JM, Wearables (2021) Physical Activity, and Exercise Testing in Liver Disease. Semin Liver Dis 41:128–135. https://doi.org/10.1055/s-0040-1716564
45. Duarte-Rojo A, Brown RA, Bloomer PM, Nunez Duarte M, Grubbs RK, Hernaez R (2022) A Telemedicine Alternative to the 6-Minute Walk Test Using Personal Activity Trackers in Liver Transplant Candidates. Transpl Direct 8:e1347. https://doi.org/10.1097/TXD.0000000000001347
46. Duarte-Rojo A, Bux R, Sliwa J (2024) Untangling frailty, sarcopenia, and physical fitness in cirrhosis. Clin Liver Dis 23:e0213. https://doi.org/10.1097/CLD.0000000000000213
47. Wang M, Shui AM, Ruck J, Huang C-Y, Verna EC, King EA et al (2024) Clinically relevant cut-points for changes in the Liver Frailty Index are associated with waitlist mortality in patients with cirrhosis. Liver Transpl Off Publ Am Assoc Study Liver Dis Int Liver Transpl Soc 30:991–1001. https://doi.org/10.1097/LVT.0000000000000418
48. Meena BL, Taneja S, Tandon P, Sahni N, Soundararajan R, Gorsi U et al (2023) Home-based intensive nutrition therapy improves frailty and sarcopenia in patients with decompensated cirrhosis: A randomized clinical trial. J Gastroenterol Hepatol 38:210–218. https://doi.org/10.1111/jgh.16035
49. Jetten WD, Hogenbirk RNM, Van Meeteren NLU, Cuperus FJC, Klaase JM, De Jong R (2022) Physical Effects, Safety and Feasibility of Prehabilitation in Patients Awaiting Orthotopic Liver Transplantation, a Systematic Review. Transpl Int 35:10330. https://doi.org/10.3389/ti.2022.10330
50. Abow-Mohamed I, Martel M, Janaudis-Ferreira T, Gillis C, Geraci O, Albader F et al (2026) Feasibility, safety, and effectiveness of prehabilitation programs in patients awaiting liver transplantation: A systematic review and meta-analysis. Am J Transpl Off J Am Soc Transpl Am Soc Transpl Surg 26:1110–1120. https://doi.org/10.1016/j.ajt.2026.01.007

51. Lai JC, Dodge JL, Kappus MR, Wong R, Mohamad Y, Segev DL et al (2021) A Multi-Center Pilot Randomized Clinical Trial of a Home-Based Exercise Program for Patients with Cirrhosis: The Strength Training Intervention (STRIVE). Am J Gastroenterol 116:717–722. https://doi.org/10.14309/ajg.0000000000001113
52. Duarte-Rojo A, Bloomer PM, Grubbs RK, Stine JG, Ladner D, Hughes CB et al (2023) Use of a Mobile-Assisted Telehealth Regimen to Increase Exercise in Transplant Candidates: A Home-Based Prehabilitation Pilot and Feasibility Trial. Clin Transl Gastroenterol 14:e00601. https://doi.org/10.14309/ctg.0000000000000601
53. Davis JF, van Rooijen SJ, Grimmett C, West MA, Campbell AM, Awasthi R et al (2022) From Theory to Practice: An International Approach to Establishing Prehabilitation Programmes. Curr Anesthesiol Rep 12:129–137. https://doi.org/10.1007/s40140-022-00516-2
54. Kumnig M, Jowsey-Gregoire SG, Gruber A, Kofler MM, Gordon EJ (2025) Development of a patient-centered peer-mentoring program for kidney transplant patients: a qualitative study. Front Psychol [Internet] Front. [cited 2026 July 30];16 https://doi.org/10.3389/fpsyg.2025.1712921
55. Pahari H, Tripathi S, Nundy S (2025) What about the caregivers? Rethinking chronic illness support in the age of transplantation. World J Transpl 15:104230. https://doi.org/10.5500/wjt.v15.i3.104230
56. Verma M, Horrow J, Carmody S, Navarro V (2024) Unmet Needs and Burden of Caregivers of Patients Being Evaluated for a Liver Transplant Are Similar to Those of Cancer Caregivers. Am J Hosp Palliat Med SAGE Publications Inc 41:391–397. https://doi.org/10.1177/10499091231176297
57. Zarit SH, Reever KE, Bach-Peterson J (1980) Relatives of the impaired elderly: correlates of feelings of burden. Gerontologist 20:649–655. https://doi.org/10.1093/geront/20.6.649

Figures

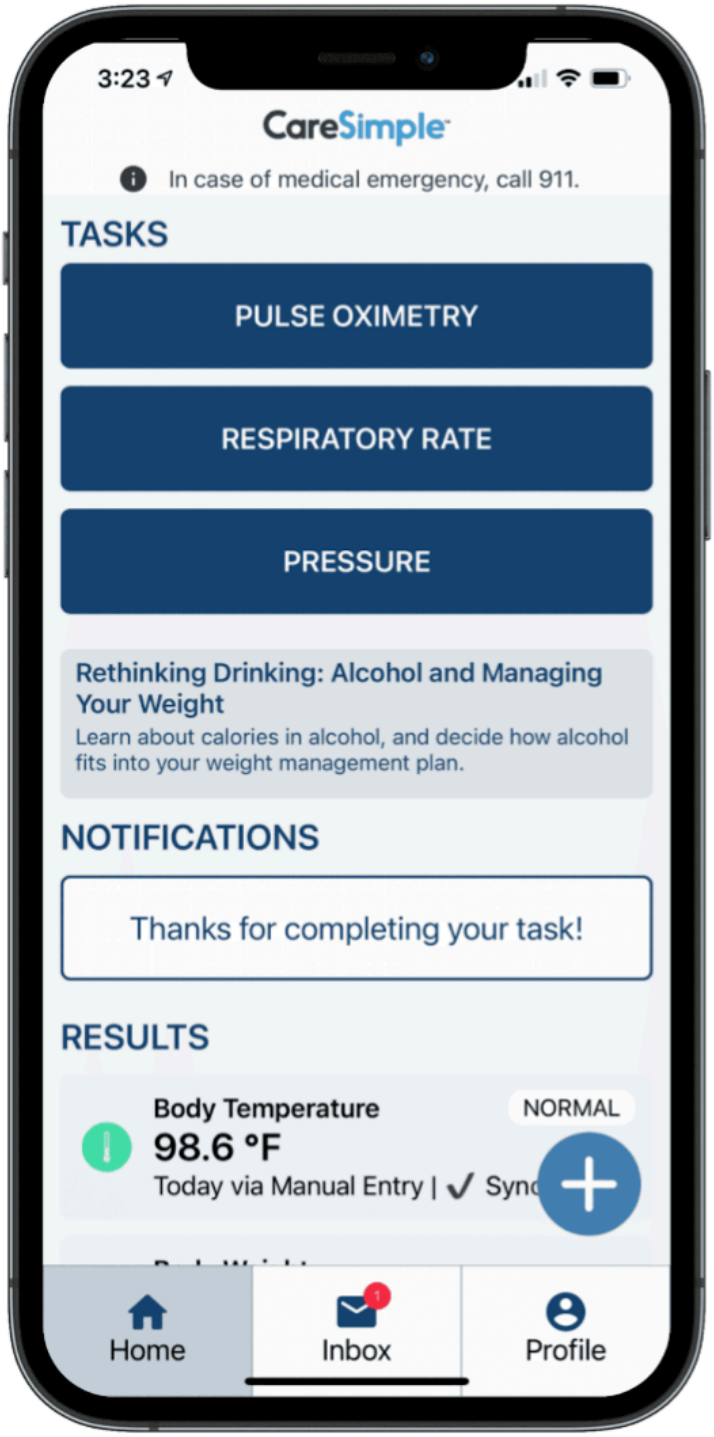


Figure 1

Screenshot of the CareSimple® smartphone application used by patients

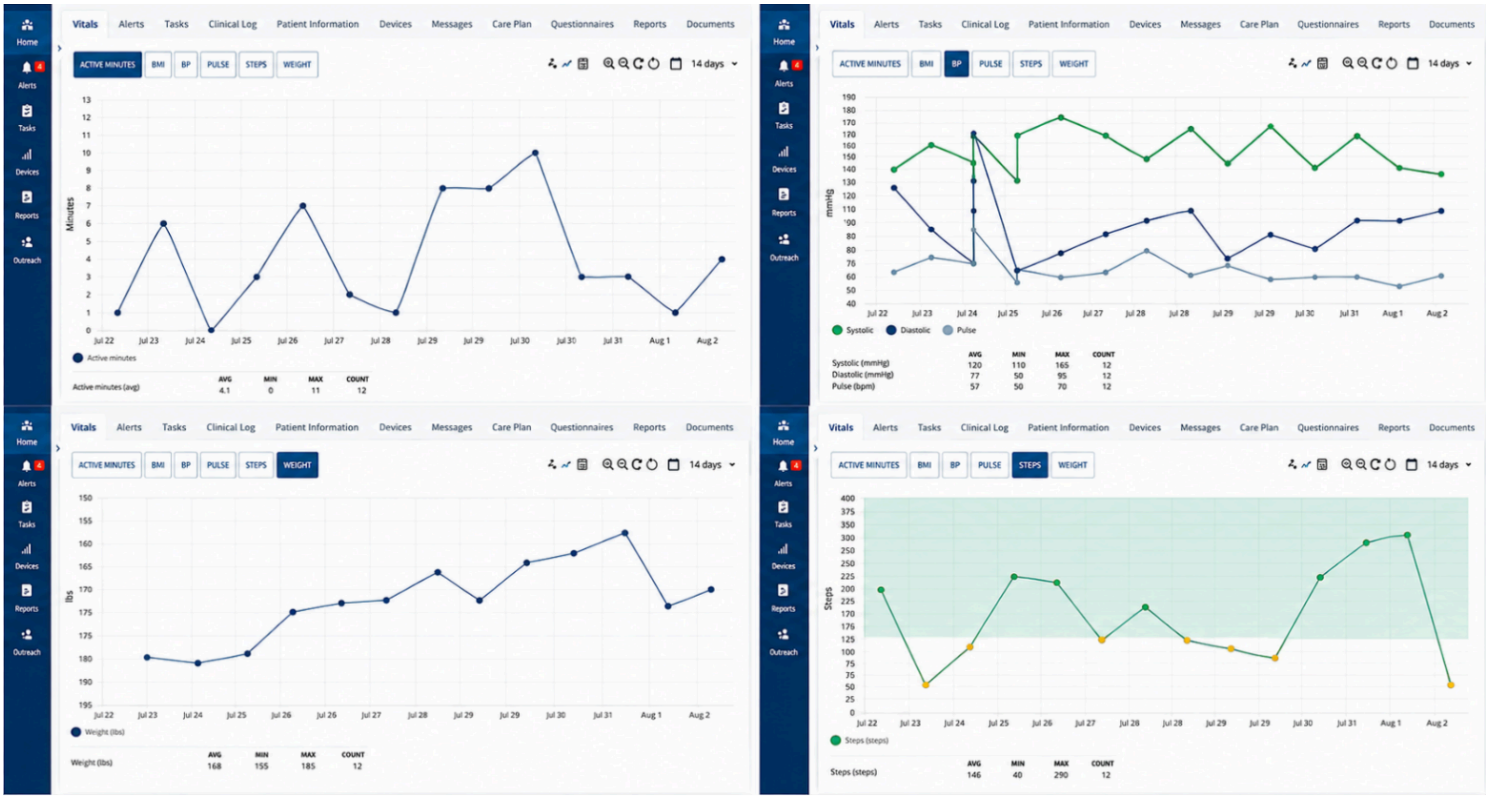


Figure 2

Screenshot of the application tracking data collection from the connected devices

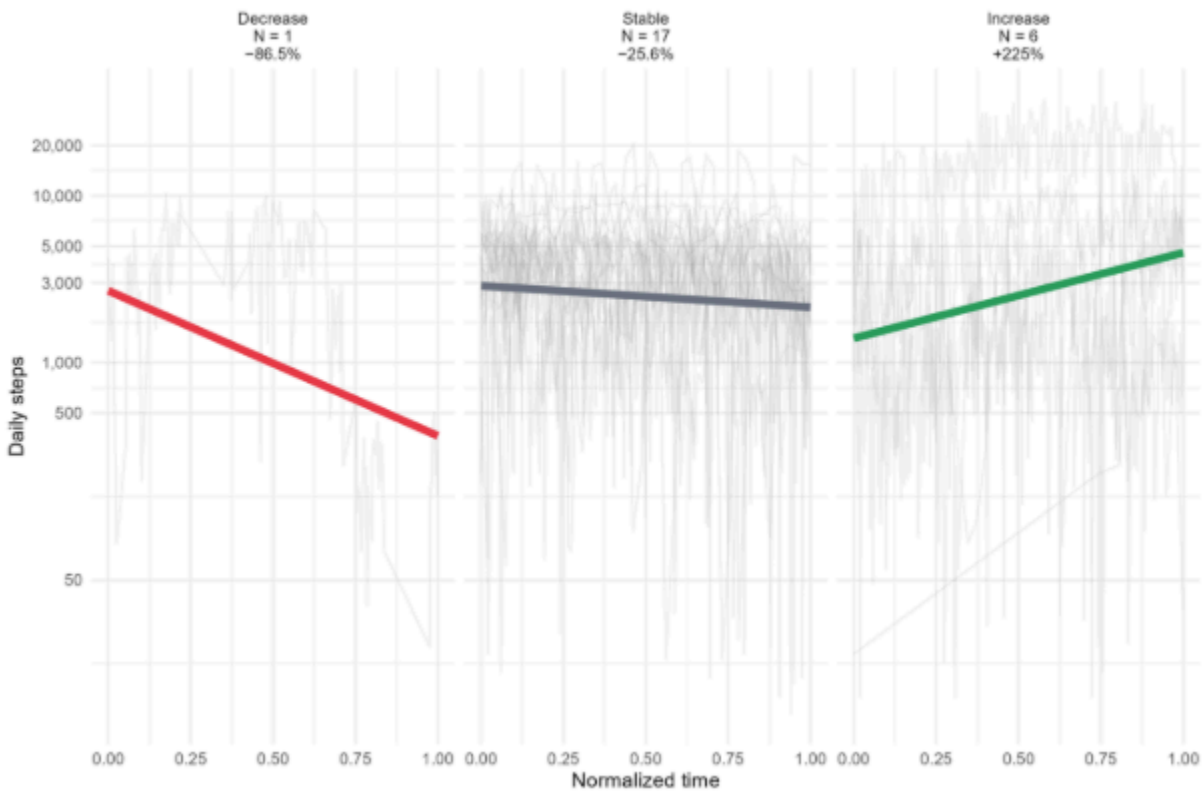


Figure 3

Daily walking activity among recruited patients (N = 24)

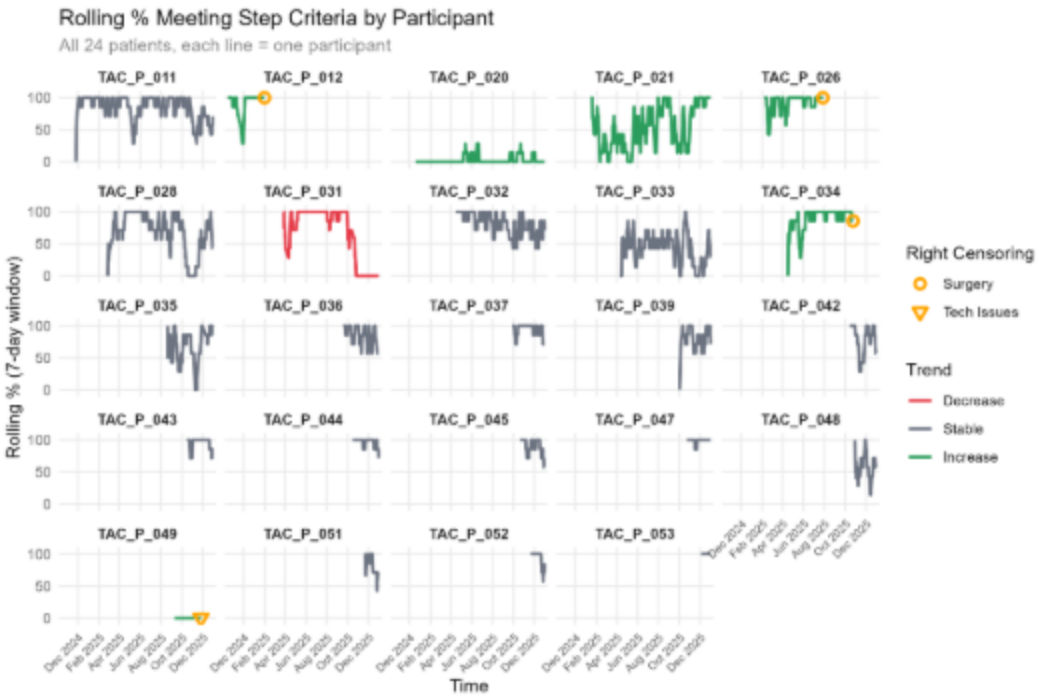


Figure 4

Curve of the weekly percentage of daily step goal achievement.

Supplementary Files

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- Appendixs.docx