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A mobile app significantly improves adherence to multimodal prehabilitation in elective colon cancer surgery: A Prospective Quasi-Randomized Controlled Pilot Study

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Abstract

Purpose

To compare adherence to a multimodal home-based prehabilitation program delivered through a mobile application versus a paper-based standard format in patients undergoing elective colon cancer surgery, and to evaluate preoperative functional status, postoperative outcomes, app usability and patient satisfaction.

Methods

This prospective quasi-randomized controlled pilot study included patients with resectable colon cancer scheduled for elective surgery. Patients were assigned sequentially to either app-based prehabilitation (APP, n = 33) or standard paper-based prehabilitation (stPREH, n = 32). The multimodal program included aerobic and resistance exercise, relaxation techniques and high-protein nutritional supplementation. Primary outcome was adherence, defined as the percentage of completed prehabilitation days. Secondary outcomes included preoperative functional outcomes, 30-day postoperative outcomes, app usability and patient satisfaction.

Results

Adherence was significantly higher in the APP versus stPREH group (92.3% vs. 21.9%; $p < 0.001$). Adherent patients achieved a clinically meaningful improvement in 6MWT compared to nonadherent patients (Δ59m vs. Δ3m; $p = 0.043$). Postoperative outcomes were comparable (complications 23% vs. 25%; median length of stay 5 days both groups; $p = 0.80$). App usability was rated above average (SUS median 72.5 points) and patient satisfaction was high and equivalent in both groups (CSQ-8 median 31 points; $p = 0.94$).

Conclusions

PREHapp significantly improved adherence to multimodal home-based prehabilitation while demonstrating good usability and high patient satisfaction. Although improved adherence did not translate into significant differences in preoperative functional or short-term postoperative outcomes, the findings support the feasibility of app-based prehabilitation in elective colon cancer surgery.

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INTRODUCTION

Colorectal cancer represents one of the leading causes of cancer-related morbidity and mortality worldwide, ranking third in incidence and second in cancer-related deaths globally [1]. Surgical resection remains the mainstay of curative-intent treatment for localized disease. However, elective colectomy is associated with postoperative complication rates of 20–40% depending on patient risk profile and surgical complexity [2, 3]. A large proportion of patients presenting for colorectal cancer surgery exhibit reduced functional capacity, malnutrition, or psychological distress; these modifiable risk factors each predict an increase in postoperative morbidity and a delay in recovery [4, 5]. In this context, multimodal prehabilitation has emerged as a proactive perioperative strategy designed to optimize patients' physical, nutritional, and psychological status before surgery and has been shown to improve preoperative functional capacity in randomized controlled trials [6–8].

Despite this evidence base, the clinical implementation of prehabilitation programs faces adherence as the fundamental challenge. [3, 4, 9]. Reported participation and adherence rates across prehabilitation studies in colorectal cancer surgery vary widely, ranging from 15% to 100%, reflecting the considerable heterogeneity in program design, delivery format, and population characteristics. A recent systematic review identified logistical barriers, including transportation burden, scheduling conflicts, and the requirement for repeated hospital visits, as the primary drivers of nonadherence (9). Home-based prehabilitation has been proposed as a scalable alternative, but its effectiveness is contingent on patients' ability to self-manage structured exercise, nutritional, and psychological interventions without direct professional supervision [5]. In this setting, the format of program delivery becomes a critical determinant of adherence and clinical effectiveness.

The proliferation of mobile health (mHealth) technologies has created new opportunities to deliver home-based prehabilitation through real-time guidance, automated reminders, progress monitoring, and multimedia educational content accessible at any time and location [10, 11]. App-based delivery eliminates the need for repeated hospital attendance while preserving the structure and accountability mechanisms that drive adherence [12].

Emerging evidence supports the feasibility of app-based prehabilitation in major abdominal surgery and may even optimize preoperative outcomes [10, 11, 13, 14]. In the context of Enhanced Recovery After Surgery (ERAS) protocols, digital health tools have demonstrated high acceptability and may enhance adherence to perioperative interventions [15]. Furthermore, a digital remote care solution implemented in patients undergoing colorectal cancer surgery within the Spanish healthcare system achieved high adherence rates in 74.4% of participants [16]. However, no controlled study to date has evaluated adherence as the primary outcome of a mobile app-based prehabilitation program in colon cancer surgery, and any study directly compared app-based delivery against an equivalent paper-based format under controlled conditions either.

The aim of this study was to evaluate adherence to a multimodal home-based prehabilitation program delivered via a purpose-built mobile application (PREHapp) compared with a paper-based standard

format in patients undergoing elective colon cancer surgery, and its association with preoperative functional improvement and postoperative outcomes. App usability and patient satisfaction were also evaluated as secondary outcomes.

MATERIALS AND METHODS

Study design and setting

A prospective quasi-randomized controlled pilot study was conducted at the Colorectal Surgery Unit of the Hospital General Universitario de Elche (Elche, Spain) between October 2021 and August 2024. The study was approved by the Institutional Ethics Committee of the Hospital General Universitario de Elche (reference PI 78/2021), conducted in accordance with the Declaration of Helsinki, and prospectively registered at ClinicalTrials.gov (NCT05608967) on October 10, 2022. Written informed consent was obtained from all participants prior to enrollment.

Patients

Patients aged 18 years or older with a confirmed diagnosis of resectable colon cancer scheduled for elective surgery were considered for inclusion, provided a minimum interval of 2 weeks existed between diagnosis and planned surgery date and the patient owned an Android smartphone. Patients were excluded if they met any of the following criteria: unresectable colon cancer; cognitive or physical impairment precluding comprehension of study instruments; insufficient command of written and spoken Spanish; current use of nutritional supplements prior to enrollment; American Society of Anesthesiologists (ASA) physical status classification IV or V; or refusal to participate.

Eligible patients were allocated sequentially to either the mobile app-based prehabilitation group (APP) or the paper-based standard prehabilitation group (stPREH). Allocation to study groups was performed using a sequential alternating assignment method at the time of enrollment. As computer-generated random sequence allocation was not used, the study is considered quasi-experimental in design. A CONSORT-compatible flow diagram is presented in Fig. 1.

Interventions

Prehabilitation program

Both groups received an identical multimodal prehabilitation program, comprising four components delivered over the interval between the baseline outpatient visit and the day prior to surgery. Program content was equivalent across groups; delivery format was the sole experimental variable. The four components were: (1) aerobic exercise, individualized in intensity based on baseline 6MWT performance without exceeding theoretically calculated maximum heart rate; (2) resistance training with illustrated

exercise routines and specified repetitions; (3) relaxation exercises via guided audio-visual content (15–30 minutes daily); and (4) high-protein nutritional supplementation (Nutavant® Plus) to ensure a minimum protein intake of 1.2–1.5 g/kg/day. The recommendation was to perform prehabilitation program daily if possible, or at least three times a week.

PREHapp mobile application (APP group)

PREHapp is a purpose-built mobile application developed in collaboration with a third-party software provider (Dextro, Spain). The platform comprises two interfaces: a patient-facing mobile application and a web-based clinician dashboard (Fig. 2). Each patient accessed their individualized profile by scanning a unique QR code generated through the web interface. Application functionalities included: automatic aerobic exercise tracking via Google Fit synchronization (smartphone accelerometer); illustrated video tutorials for resistance exercise with automated completion logging; embedded relaxation video content; daily nutritional logging; end-of-day adherence confirmation prompts.

Standard format Prehabilitation (stPREH group)

Patients assigned to stPREH group received the same prehabilitation program in paper-based format, including written exercise instructions with illustrated guides, printed nutritional recommendations, and a daily paper adherence sheet for self-reporting of all program components.

Outcome measures

Adherence

On the day before surgery, patients were asked whether they had followed the prehabilitation program and were requested to submit their activity records. Patients in the APP group submitted their records through PREHapp, whereas those in the standard prehabilitation group provided paper-based activity logs. Adherence status was determined according to activity record submission, regardless of the delivery format. Only patients who submitted activity records were considered adherent.

Adherence was defined as the percentage of completed prehabilitation days relative to the total number of days prescribed for each patient. Patients were further categorized into high and low-adherence groups using the median adherence rate as the cutoff value.

Functional Capacity

Functional capacity was assessed using the 6-minute walk test (6MWT) performed on a treadmill [17]. The 6MWT was performed at two time points: the baseline outpatient visit and the day prior to surgery. The minimal clinically important difference for this test has been established at 25 meters in surgical populations [18].

Muscle Mass and Function

Phase angle (PhA) was assessed by bioelectrical impedance analysis (BIA) using a calibrated TANITA MC 780-S MA device (Suite Biologica® software v11.0) as a validated proxy for cellular integrity and muscle mass [19]. Low PhA was defined as < 4.8° in men and < 4.2° in women [20, 21]. Handgrip strength (HGS) was measured using a Jamar® hydraulic dynamometer. Low HGS was defined as < 27 kg in men and < 16 kg in women [22]. Both PhA and handgrip strength were measured at baseline and the day prior to surgery.

Psychological Status

Anxiety and depression were assessed using the validated Spanish version of the Hospital Anxiety and Depression Scale (HADS) [23], administered at the baseline visit and the day prior to surgery.

App Usability and Patient Satisfaction

App usability was assessed using the validated Spanish version of the System Usability Scale (SUS), a standardized 10-item questionnaire measuring the ease of use and overall user experience of digital tools [24]. The SUS is a 10-item questionnaire that provides a global measure of perceived usability. Scores range from 0 to 100, with higher scores indicating better usability. A score of at least 62.7 was considered acceptable, whereas scores of 68 or higher were considered above average [25, 26]. Participants completed the SUS on the day prior to surgery.

Overall satisfaction with the prehabilitation program was assessed one month after surgery during the postoperative follow-up visit using the Client Satisfaction Questionnaire (CSQ-8). The CSQ-8 consists of 8 items rated on a 4-point Likert scale. Total scores range from 8 to 32, with higher scores indicating greater satisfaction [27].

Postoperative Outcomes

Postoperative morbidity at 30 days was classified according to the Clavien-Dindo classification [28]. Additional outcomes included length of hospital stay, anastomotic leak, reoperation, readmission, and 30-day mortality.

Statistical Analysis

The analysis followed the intention-to-treat (ITT) principle with respect to group allocation. However, due to the absence of outcome data in seven APP patients caused by technical failures, the primary analysis was conducted on available cases (complete-case analysis). A sensitivity analysis comparing baseline characteristics between excluded APP patients (n = 7) and both study groups was performed to assess potential bias. Continuous variables were expressed as mean ± SD or median [IQR] according to distributional assessment. Between-group comparisons were performed using independent t-test or Wilcoxon rank-sum test. Categorical variables were analyzed using chi-square test or Fisher exact test. Multivariable models were constructed adjusting for age, sex, Body Mass Index (BMI), ASA

classification, and intervention group. Linear regression was used to model change in 6MWT distance; quasi-Poisson regression was used for length of hospital stay. Statistical significance was set at $p < 0.05$. All analyses were performed using R version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Baseline Characteristics and Postoperative Outcomes

A total of 116 patients were assessed for eligibility, of these, 65 met inclusion criteria and were allocated to APP (n = 33) or stPREH (n = 32) group. Within APP group, 7 patients experienced technical failures due to QR code scanning failure at enrollment, precluding outcome data collection. The primary analysis was conducted on 58 patients (APP: n = 26; stPREH: n = 32).

Patients in the APP group were younger than those in the stPREH group (mean age 65 ± 8 vs. 71 ± 11 years). Among the 7 patients excluded from the APP group, the mean age was 72.1 years. Median prehabilitation duration was similar (APP: 26 [IQR 24.3–30.8] days; stPREH: 26.5 [IQR 21–31.5] days).

Thirty-day postoperative outcomes were comparable. Median length of stay was 5 days in both groups ($p = 0.80$), and overall complication rates were 23% in the APP vs. 25% in the stPREH group ($p = 0.90$). No statistically significant differences were observed in anastomosis leak, readmission or reoperation rates. Baseline demographic, clinical characteristics and 30-day postoperative outcomes are presented in Table 1.

Table 1
Baseline Characteristics and 30-Day Postoperative Outcomes

Age (years), mean ± SD		**TOTAL (n = 58)**	**APP (n = 26)**	**stPREH (n = 32)**
		68 ± 10	**65 ± 8**	**71 ± 11**
Sex, n (%)	**Male**	35 (60%)	18 (69%)	17 (53%)
	Female	23 (40%)	8 (31%)	15 (47%)
BMI, mean ± SD		27.8 ± 4.5	28.4 ± 4.5	27.3 ± 4.5
Smoking status, n (%)	**Smoker**	6 (10%)	0 (0%)	6 (19%)
	Non-smoker	41 (71%)	22 (85%)	19 (59%)
	Ex-smoker	11 (19%)	4 (15%)	7 (22%)
ASA classification, n (%)	**I**	11 (19%)	4 (15%)	7 (22%)
	II	29 (50%)	16 (62%)	13 (41%)
	III	18 (31%)	6 (23%)	12 (38%)
Surgical procedure, n (%)	**Right hemicolectomy**	33 (57%)	11 (42%)	22 (69%)
	Left hemicolectomy	3 (5.2%)	1 (4%)	2 (6%)
	Sigmoidectomy	21 (36%)	13 (50%)	8 (25%)
	Exploratory laparoscopy	1 (1.7%)	1 (4%)	0 (0%)
Surgical approach, n (%)	**Laparoscopic**	34 (59%)	15 (58%)	19 (59%)
	Robotic	23 (40%)	11 (42%)	12 (38%)
	Open	1 (1.7%)	0 (0%)	1 (3%)
Prehabilitation days, median [IQR]		26 [23.3–31]	26 [24.3–30.8]	26.5 [21-31.5]
Length of stay (days), median [IQR]		5 [4–6]	5 [4–6]	5 [4–6]
Complications (Clavien-Dindo)	**Overall, n (%)**	14 (24%)	6 (23%)	8 (25%)
	0- I, n (%)	50 (86%)	22 (85%)	28 (88%)
	II - V, n (%)	8 (14%)	4 (15%)	4 (12%)
Anastomosis leak, n (%)	**SI**	3 (5.2%)	0	3 (9.4%)
	NO	55 (94.8)	26 (100%)	29 (90,6%)

Age (years), mean ± SD		TOTAL (n = 58)	APP (n = 26)	stPREH (n = 32)
		68 ± 10	65 ± 8	71 ± 11
Readmission, n (%)	SI	5 (8.6%)	2 (7.7%)	3 (9.4%)
	NO	53 (91.4%)	24 (92,3%)	29 (90.6%)
Reoperation (30-day), n (%)	SI	5 (8.6%)	1 (3.8%)	4 (12.5%)
	NO	53 (91.4%)	25 (96.2%)	28 (87,5%)
Mortality, n (%)		1 (3.8%)	0	0.4

Adherence

The primary outcome was significantly higher in APP compared to stPREH (92.3% [24/26] vs. 21.9% [7/32] adherent patients; p < 0.001). Within APP group, the median overall adherence was 48.7% [IQR 35–66]. Patients were classified into high adherence (n = 12) and low adherence (n = 12) subgroups using the median adherence rate as the cutoff value. High-adherence patients demonstrated significantly greater adherence across all individual program components compared to low-adherence patients, with no significant difference in total prehabilitation duration (Table 2).

Table 2
Prehabilitation program adherence stratified in the APP group

Prehabilitation days, median [IQR]	TOTAL APP group (n = 24)	LOW-ADHERENCE (n = 12)	HIGH-ADHERENCE (n = 12)	*p value*
	26 [24-30.5]	27.5 [25-31.5]	25 [22.5–27.5]	0.2
Overall adherence (%), median [IQR]	48.7 [35–66]	35 [15–43]	66 [56–69]	< 0.001
Aerobic exercise (days), median [IQR]	12 [9–19]	10 [6–12]	15 [12–22]	0.006
Resistance training (days), median [IQR]	11 [6–17]	6 [3–10]	17 [12–22]	< 0.001
Relaxation exercises (days), median [IQR]	12 [6–15]	6 [3–10]	14 [12–21]	0.001
Nutritional supplementation (days), median [IQR]	12 [8–17]	9 [6–13]	15 [12–20]	0.043

Functional Outcomes

At the baseline visit, APP patients exhibited significantly higher handgrip strength (37 ± 10 vs. 30 ± 11 kg; p = 0.013) and higher phase angle values (5.52 ± 0.52° vs. 5.07 ± 0.65°; p = 0.005) compared to stPREH patients. On the contrary, no significant differences were observed in baseline 6MWT or HADS scores (Table 3). No cases of low phase angle or low handgrip strength were recorded in APP group at either time point. In stPREH group, prevalence of low phase angle was 12.5% at baseline and 17.9% at the preoperative assessment; low handgrip strength criteria were present in 9.4% of patients at baseline and none before the operation.

Table 3. Functional Outcomes

	Baseline APP[a] (n = 26)	**Baseline stPREH[a] (n = 32)**	**Δ APP[b] (n = 26)**	**Δ stPREH[b] (n = 32)**	***Δ p value***
6MWT (m)	388 ± 99	342 ± 122	32 [0–18]	27 [-43–77]	0.2
Handgrip strength (kg)	37 ± 10	30 ± 11	− 1 [-4–2]	2 [-2–4]	0.054
Phase angle (°)	5.52 ± 0.52	5.07 ± 0.65	0.1 [0–0.3]	0.1 [-0.15–0.25]	0.3
HADS Anxiety	6.5 ± 3.7	6.3 ± 3.7	-1 [-2–0]	-0.5 [-3–1]	> 0.9
HADS Depression	2.85 ± 2.57	4.00 ± 4.01	-1 [-2–0]	-1.5 [-3–0]	0.2

[a] *mean ± SD;* [b] *median [IQR]*

No statistically significant differences were observed between the two groups regarding functional changes from baseline to the preoperative assessment across any measured outcome. The change in 6MWT distance was + 32 m [IQR 0–18] in APP and + 27 m [IQR − 43 to 77] in stPREH (p = 0.20). Phase angle and HADS score change was minimal and equivalent in both groups (Table 3).

Pre and Postoperative Outcomes Stratified by Adherence

Adherent patients independently to the group assigned (n = 31) demonstrated a statistically significant improvement in 6MWT compared to nonadherent patients (Δ + 59 m [IQR 2–110] vs. Δ + 3 m [IQR − 57 to 68]; p = 0.043), twice the minimal clinically difference of 25m (Table 4).

Table 4
Functional outcomes stratified by adherence

Δ6MWT (m), median [IQR]	**NONADHERENT (n = 27)**	**ADHERENT (n = 31)**	***p value***
	3 [-57-68]	**59 [2–110]**	**0.043**
ΔHandgrip strength (kg), median [IQR]	0.5 [-4–4]	1 [-2–3]	0.9
ΔPhase angle (°), median [IQR]	0.1 [-0.1–0.2]	0.15 [0–0.3]	0.2
ΔHADS Anxiety, median [IQR]	0 [-2.5–1.5]	-1 [-3–0]	0.4
ΔHADS Depression, median [IQR]	-1 [-2.5–0]	-1.5 [-4–0]	0.6

In the multivariable linear regression model adjusted for age, sex, BMI, ASA classification, and intervention group, adherence was not independently associated with change in 6MWT distance (β=+32 m; 95% CI − 32 to 95; p = 0.30).

Analysis stratified by adherence status revealed no significant differences in postoperative outcomes between adherent and nonadherent patients. Within APP, the high-adherence subgroup showed numerically lower complication rates (17% vs. 33%; p = 0.60) and readmission rates (0% vs. 17%; p = 0.20) compared to the low-adherence subgroup.

App Usability and Patient Satisfaction

Of the 32 patients allocated to the APP group, 75% (24/32) actively used the application. The most common reason for nonuse was failure to complete the QR code scanning process during enrollment, followed by persistent connectivity issues with the application. Of those who used the app, 84.6% (22/26) completed the SUS questionnaire on the day prior to surgery. Median SUS score was 72.5 points. No statistically significant correlation was observed between SUS score and overall adherence (Spearman ρ = 0.33; p = 0.13).

The CSQ-8 satisfaction questionnaire was completed by 88% of patients across both groups. Median satisfaction scores were equivalent between groups (CSQ-8 median 31 points in both groups; p = 0.94).

DISCUSSION

This study provides the first controlled evidence that a purpose-built mobile application substantially improves adherence to multimodal home-based prehabilitation in patients undergoing elective colon cancer surgery, achieving a fourfold increase relative to an equivalent paper-based format (92.3% vs. 21.9%; p < 0.001).

The adherence rate of 92.3% observed in APP group places this study at the upper boundary of what has been reported in the prehabilitation literature for colorectal cancer surgery. A recent systematic review encompassing 89 studies and more than 13000 patients reported adherence rates ranging from 15 to 100% [9]. Within this broad range, the 21.9% adherence rate in our paper-based control group reflects the well-documented difficulty of sustaining unsupervised home-based exercise programs without digital scaffolding. On the contrary, the 92.3% adherence rate achieved in the APP group in a fully home-based, unsupervised format approaches the ceiling observed only in highly supervised in-person programs. This finding support that the adherence gap between supervised and unsupervised prehabilitation may be substantially narrowed through structured digital delivery, without the personnel costs and logistical burden of in-person supervision.

The present study adds to a growing body of evidence supporting the feasibility and acceptability of app-based prehabilitation in colorectal cancer surgery. One study assessing the Fit4Surgery app in 100 colorectal cancer patients aged above 60 years and reported high long-term adherence with program costs reduced by approximately half compared to supervised multimodal prehabilitation [14]. Likewise, a comprehensive digital coaching platform integrated into the ERAS pathway demonstrated excellent adherence throughout the perioperative period [29], and, within the Spanish healthcare system, a remote care platform achieved high adherence in 74.4% of 227 patients undergoing colorectal cancer surgery [16]. Similarly, the PROTEGO MAXIMA trial confirmed that app-guided exercise prescription is both feasible and safe in the preoperative oncological setting [30].

Although these findings support the feasibility of PREHapp, understanding the factors associated with adherence requires consideration of app usability, patient satisfaction, and implementation barriers. PREHapp achieved a median SUS score of 72.5, comparable with those reported for other perioperative mHealth applications, including the score of 70.7 reported by Van der Velde et al. [26], and high usability scores reported by Wang et al. [12]. Likewise, CSQ-8 scores were equally high in both groups (median 31), indicating similar levels of satisfaction with both delivery modalities and suggesting that the observed adherence differences were more likely related to implementation barriers than to differences in perceived program value [31]. These findings are consistent with those of the multicenter Be Prepared trial, in which the app improved patient satisfaction but did not translate into better postoperative functional recovery [15]. Together, these results suggest that good usability alone may be insufficient to promote adherence and that additional engagement strategies, such as structured activity logging, may be required to support sustained participation in prehabilitation programs.

Importantly, the 25% rate of technical issues in the APP group, primarily attributable to QR code onboarding failure, underscores the real-world implementation challenges of app-based prehabilitation in routine clinical practice [32]. Optimizing the onboarding process should therefore be a priority for future iterations of PREHapp.

However, the higher adherence observed with PREHapp, was not translated into statistically significant differences in preoperative functional or 30-day postoperative outcomes. Both groups showed similar

improvement in 6MWT distance, handgrip strength, and phase angle. Postoperative complication rates, length of stay, and readmission rates were also comparable. These findings may not be contradictory because both groups received the same prehabilitation program, and the study was designed to evaluate the added value of the delivery format rather than the effectiveness of the program itself. The adherence-stratified analysis offers an important complementary perspective. Adherent patients, regardless of delivery format, showed a significant improvement in the 6MWT compared to nonadherent patients ($p = 0.043$). Although this association was attenuated after multivariable adjustment, the unadjusted difference exceeded the established minimal clinically important difference for the 6MWT. Together, these findings provide a within-study signal that the functional benefits of prehabilitation may be related to the degree of program adherence, consistent with the broader exercise science literature and Carli's conceptual framework linking preoperative functional reserve to postoperative recovery capacity [33].

The absence of significant differences in postoperative outcomes is consistent with previous randomized trials of multimodal prehabilitation. The PREHAB trial similarly reported improvements in functional capacity without a corresponding reduction in postoperative complications [6]. Carli et al. found no significant reduction in 30-day complications with multimodal prehabilitation in frail colorectal cancer patients [7]. In populations with an overall low surgical risk, as reflected by the low complication rates in both groups (23–25%), the expected effect size of prehabilitation on complication rates may require substantially larger sample sizes to detect.

The findings of this study should be interpreted in light of its limitations. First, the quasi-randomized sequential allocation design is the most significant methodological limitation. The resulting baseline age imbalance likely reflecting greater digital device familiarity in younger patients, introduces residual confounding that multivariable adjustment cannot fully eliminate. Future studies must use computer-generated randomization with concealed allocation. Also, the exclusion of patients without Android smartphones introduces a technology-related selection bias limiting generalizability to older or less digitally literate patients. The complete-case analysis, necessitated by technical failures in seven APP group patients, deviates from the ITT principle; although sensitivity analysis revealed no significant baseline differences, attrition bias cannot be fully excluded. Finally, the pilot sample size of 58 patients provides insufficient statistical power to detect clinically meaningful differences in postoperative complication rates, and all postoperative findings should be considered hypothesis-generating.

In summary, our study suggests that the mobile application serves mainly as a facilitator for behavioral implementation instead of acting as an independent modifier of functional outcomes. Although it does not alter the therapeutic content of the prehabilitation program, it may increase the likelihood that patients adhere to and complete the prescribed intervention. In home-based prehabilitation, where professionals provide limited direct supervision, this implementation support function may play an important role in determining the success of program delivery. These findings support the feasibility of app-based delivery of multimodal prehabilitation for patients undergoing colon cancer surgery. They also provide a rationale for a larger, adequately powered randomized controlled trial to determine whether

sustained digitally supported adherence leads to improved postoperative outcomes and longer-term functional recovery.

CONCLUSIONS

PREHapp significantly improved adherence to multimodal home-based prehabilitation compared with an equivalent paper-based program in patients undergoing elective colon cancer surgery. Although this did not result in significant differences in preoperative functional or short-term postoperative outcomes, the findings support the feasibility of app-based delivery of multimodal prehabilitation and demonstrate good usability and high patient satisfaction.

Declarations

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest. No author holds equity, receives honoraria, or has any financial relationship with Dextro or with the manufacturer of Nutavant® Plus nutritional supplements.

DATA AVAILABILITY

The datasets generated and analyzed during this study are available from the corresponding author (LSG; drsanchezguillen@gmail.com) upon reasonable request, subject to applicable data protection regulations (Spanish Organic Law 3/2018; EU General Data Protection Regulation 2016/679). Anonymized participant-level data may be shared for systematic reviews or individual patient data meta-analyses upon execution of a formal data sharing agreement.

AUTHOR CONTRIBUTIONS

CLG: Conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing — original draft, writing — review and editing.

LSG: Conceptualization, funding acquisition, methodology, project administration, supervision, writing — original draft, writing — review and editing.

FLRA: Conceptualization, investigation, methodology, writing — review and editing.

XB: Formal analysis, methodology, statistical analysis, writing — review and editing.

MJAQ: Data curation, investigation, writing — review and editing.

ASR: Data curation, investigation, writing — review and editing.

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Figures

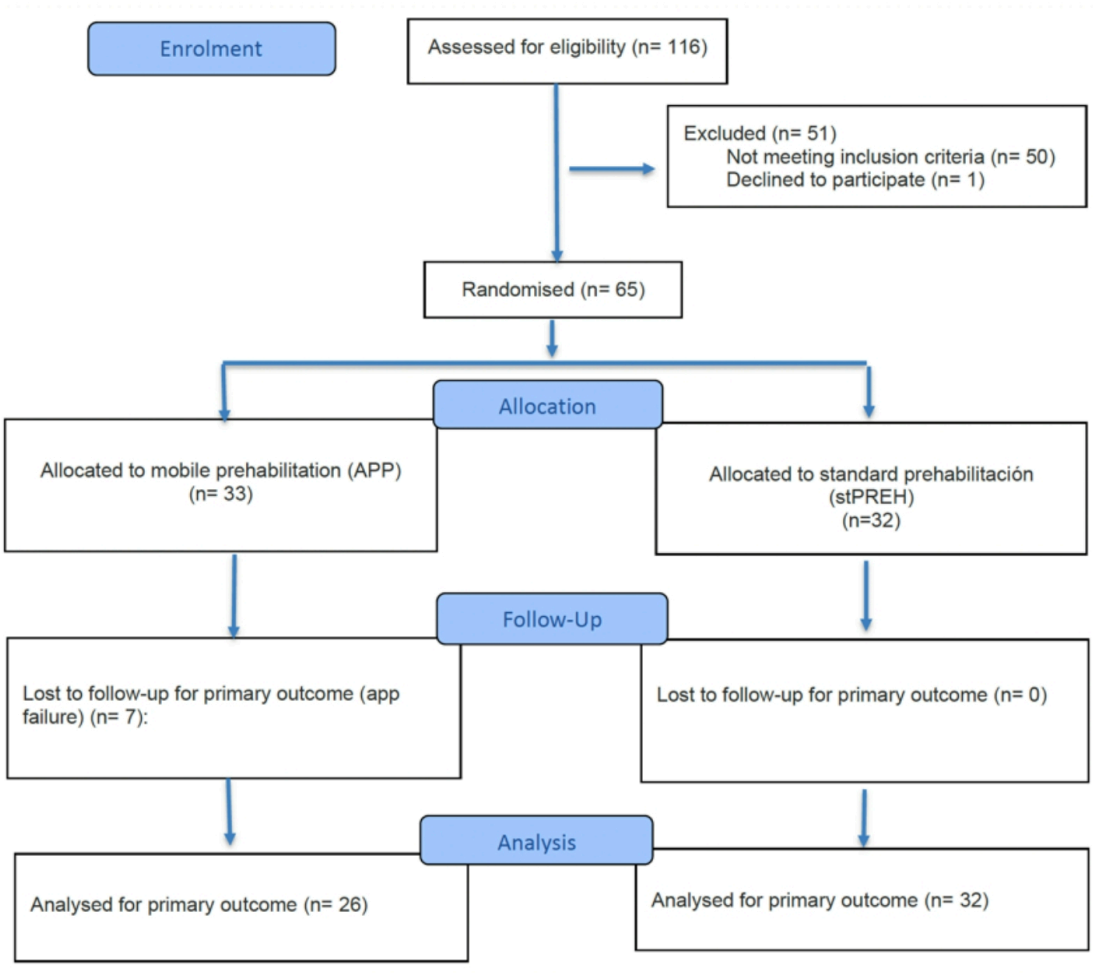


Figure 1

CONSORT 2025 Flow Diagram of the study

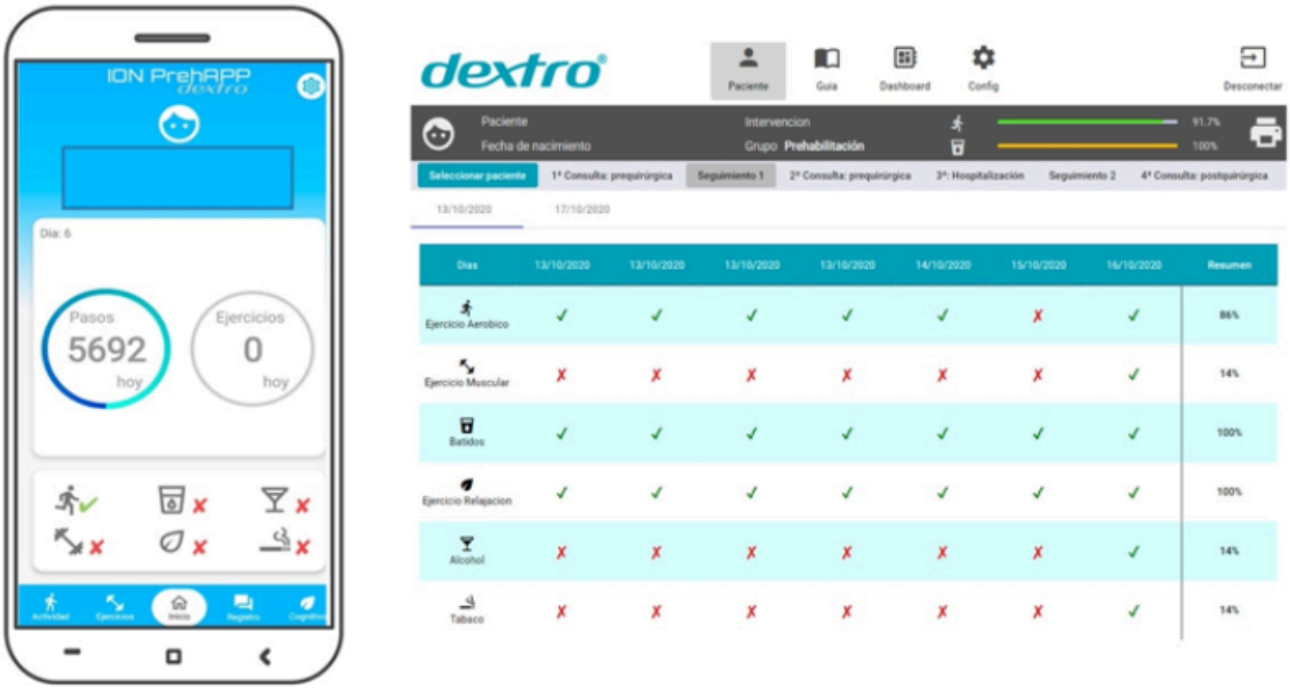


Figure 2

PREHapp and web interface