Article

Feasibility of a Preoperative e-Nursing Intervention for Older Persons Awaiting Cardiac Surgery

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Theme: Technologies for healthcare

Contribution to the discipline: This study strengthens the evidence base for preoperative nursing care in older adults, aged 65 years and over, undergoing cardiac surgery. By integrating education, breathing exercises, and remote follow-up, the e-Nursing intervention demonstrates that prehabilitation can be feasibly delivered and accepted in routine clinical settings. The findings contribute to the development of person-centered and technology-supported nursing models that enhance surgical preparation and recovery. This work advances nursing disciplinary knowledge by emphasizing the rehabilitation nurse's role in digital health interventions and by aligning preoperative care with the principles of self-management and continuity of care.

Abstract

Introduction: Cardiovascular diseases remain a major cause of morbidity and mortality among older adults. Preoperative nursing interventions can improve surgical outcomes by promoting functional recovery and reducing postoperative pulmonary complications. To date, evidence regarding the feasibility of an e-Nursing preoperative intervention on older adults awaiting cardiac surgery is scarce. **Objectives:** To test the feasibility and acceptability of a preoperative e-Nursing intervention for older adults awaiting elective cardiac surgery, focusing on postoperative complications, length of stay, and health literacy outcomes. **Materials and Methods:** A single-group cohort feasibility study was conducted in a cardiothoracic department in northern Portugal. Participants aged ≥ 65 years scheduled for elective cardiac surgery received an in-person session with a rehabilitation nurse, including breathing and mobility exercises, followed by weekly remote follow-up until surgery. Data were collected at baseline and hospital discharge using validated instruments for quality of life (EQ-5D), functional status (Barthel and Lawton indexes), health literacy (HLS-EU), and exercise capacity (6-minute walk test). Descriptive and inferential analyses were performed with SPSS v28. **Results:** Thirty participants (mean age 74 years) completed the program, with high adherence (96.7 %). Postoperative pulmonary complications occurred in 13% of participants, and the mean hospital stay was 7.2 days. Functional and health literacy scores showed slight, non-significant improvements. The intervention was well accepted by participants and healthcare staff. **Conclusions:** The e-Nursing preoperative program was feasible and acceptable for older adults awaiting cardiac surgery. Findings support the design of a future randomized trial to evaluate its effectiveness in improving recovery and reducing postoperative complications.

Keywords (Source: MeSH)

Cardiovascular diseases; heart surgery; evidence-based nursing; feasibility study; nursing.

Factibilidad de un intervención preoperatoria de enfermería virtual para personas mayores que esperan por cirugía cardiaca

Resumen

Introducción: Las enfermedades cardiovasculares siguen siendo la principal causa de morbilidad y mortalidad entre los adulto mayores. Las intervenciones de enfermería preoperatorias pueden mejorar los resultados quirúrgicos al promocionar la recuperación funcional y reducir las complicaciones pulmonares posoperatorias. A la fecha, la evidencia frente a la factibilidad de una intervención preoperatoria en adultos mayores que esperan una cirugía cardiaca es escasa. **Objetivos:** Evaluar la factibilidad y aceptación de una intervención preoperatoria virtual de enfermería para adultos mayores que esperan por cirugía cardiaca electiva, con énfasis en complicaciones posoperatorias, tiempo de hospitalización y resultados de alfabetización en salud. **Materiales y métodos:** Se realizó un estudio de factibilidad de una sola cohorte en un departamento cardiotorácico del norte de Portugal. Los participantes fueron adultos mayores de ≥ 65 años programados para cirugía electiva, quienes fueron recibidos en una sesión presencial por una enfermera de rehabilitación, que incluyó ejercicios de respiración y movilidad, y seguimiento a distancia semanal hasta la cirugía. Los datos se recolectaron al inicio del estudio y al momento del alta, usando instrumentos validados para la calidad de vida (EQ-5D), el estado funcional (Barthel and Lawton indexes), la alfabetización en salud (HLS-EU) y la capacidad de ejercicio (prueba de los 6 minutos caminando). Los análisis descriptivos e inferenciales se llevaron a cabo con el SPSS v28. **Resultados:** Treinta participantes (media de edad 74 años) completaron el programa, con adherencia alta (96,7 %). Hubo complicaciones pulmonares en el 13 % de los participantes, y la media de días de hospitalización fue de 7,2 días. Los puntajes de alfabetización funcional y en salud mostraron mejoras leves y no significativas. La intervención fue bien recibida por los participantes y los miembros del equipo de salud. **Conclusiones:** El programa preoperatorio virtual de enfermería fue factible y aceptable para los adultos mayores en espera de una cirugía cardiaca. Los resultados apoyan el diseño de una futura prueba aleatoria para evaluar su efectividad en el mejoramiento de la recuperación y la reducción de las complicaciones posoperatorias.

Palabras clave (Fuente DeCS)

Enfermedades cardiovasculares; cirugía torácica; enfermería basada en la evidencia; estudios de factibilidad; enfermería.

Viabilidade de uma intervenção de enfermagem pré-operatória virtual para pessoas idosas que aguardam cirurgia cardíaca

Resumo

Introdução: As doenças cardiovasculares continuam sendo a principal causa de morbidade e mortalidade entre pessoas idosas. Intervenções de enfermagem pré-operatórias podem melhorar os resultados cirúrgicos ao promover a recuperação funcional e reduzir as complicações pulmonares pós-operatórias. Até o momento, há poucas evidências sobre a viabilidade de uma intervenção pré-operatória em idosos que aguardam cirurgia cardíaca. Objetivos: avaliar a viabilidade e aceitação de uma intervenção de enfermagem pré-operatória virtual para idosos que aguardam cirurgia cardíaca eletiva, com ênfase em complicações pós-operatórias, tempo de hospitalização e resultados de alfabetização em saúde. **Materiais e método:** Realizou-se um estudo de viabilidade de coorte única em um departamento de cirurgia cardiotorácica no norte de Portugal. Participaram adultos com 65 anos ou mais, programados para cirurgia eletiva, que participaram de uma sessão presencial por uma enfermeira de reabilitação, incluindo exercícios de respiração e mobilidade, além de acompanhamento remoto semanal até a cirurgia. Os dados foram coletados no início e na alta, utilizando instrumentos validados para qualidade de vida (EQ-5D), estado funcional (índices de Barthel e Lawton), alfabetização em saúde (HLS-EU) e capacidade de exercício (teste de caminhada de 6 minutos). Análises descritivas e inferenciais foram realizadas com SPSS v28. **Resultados:** Trinta participantes (idade média de 74 anos) concluíram o programa, com alta adesão (96,7 %). Complicações pulmonares ocorreram em 13 % dos participantes, e o tempo médio de hospitalização foi de 7,2 dias. Os escores de alfabetização em saúde e de capacidade funcional apresentaram melhorias discretas, sem significância estatística. A intervenção foi bem aceita pelos participantes e pelos membros da equipe de saúde. **Conclusões:** O programa virtual de enfermagem pré-operatória mostrou-se viável e aceitável para pessoas idosas que aguardavam cirurgia cardíaca. Os resultados fornecem subsídios para o delineamento de um futuro ensaio randomizado, a fim de avaliar sua eficácia na melhoria da recuperação e na redução das complicações pós-operatórias.

Palavras-chave (Fonte DeCS)
Doenças cardiovasculares; cirurgia torácica; enfermagem baseada em evidências; estudos de viabilidade; enfermagem.

Introduction

Cardiovascular diseases are highly prevalent worldwide and remain a leading cause of morbidity and mortality, particularly among older people (1-3). With population ageing, the number of people undergoing cardiac surgery continues to increase, often accompanied by multiple comorbidities that heighten the risk of adverse postoperative outcomes (4-6). Elective surgery waiting times may contribute to functional decline, deconditioning, and psychological distress, which in turn can worsen recovery (7-9).

Preoperative rehabilitation has been proposed as a strategy to improve surgical outcomes. Evidence suggests that breathing and physical exercise programs may reduce postoperative pulmonary complications, enhance functional recovery, and shorten hospital stay (10-14). However, there is no consensus on a single intervention that consistently achieves these outcomes, and feasibility studies continue to be needed (15, 16).

Systematic reviews and trials of exercise-based prehabilitation and inspiratory muscle training in cardiac surgery have shown significant benefits for postoperative outcomes (10-16). Exercise-based prehabilitation has been associated with fewer postoperative pulmonary complications and improved exercise tolerance and functional status; for example, higher walk-test distances and earlier recovery of daily activities (10, 15, 16). Preoperative inspiratory muscle training has consistently increased inspiratory muscle strength and reduced the occurrence or severity of postoperative pulmonary complications, including pneumonia and atelectasis (11-14), and was associated with a mean reduction in postoperative hospital stay of approximately 1-2 days compared with usual care (12).

Programs have been delivered face to face, which may limit their scalability and accessibility for older adults who face logistical, geographic, or mobility barriers to attending in-person sessions. Digital health interventions are increasingly used to expand access to health information and support self-management (17-20). Perioperative and telehealth studies suggest that such tools can help maintain continuity of care and support preparation and recovery for older surgical patients who face mobility, geographic, or organizational barriers to attending in-person programs (19-22).

Cardiac surgery and its recovery trajectory can substantially affect older adults' health-related quality of life, particularly in domains such as mobility, usual activities and emotional well-being (23-27). Studies have shown that functional limitation and delayed recovery of daily activities are common after cardiac surgery and are closely related to patients' perceived quality of life in the months following the procedure (23-27).

Guided by the Medical Research Council (MRC) framework for complex interventions (28), the team conducted two systematic literature reviews and a qualitative study with focus groups to explore the needs of older people awaiting cardiac surgery (29, 30). Building on these findings, we developed a preoperative e-Nursing intervention integrating breathing exercises and remote follow-up.

The aim of this feasibility study was to test the acceptability and preliminary effects of a preoperative e-Nursing intervention among older people awaiting elective cardiac surgery, with a focus on postoperative pulmonary complications, hospital length of stay, health literacy, and quality of life.

Methods

Design

We conducted a single-group cohort feasibility study corresponding to Phase II of the Medical Research Council (MRC) framework for complex interventions (28). This phase focuses on assessing the acceptability, implementation, and preliminary effects of complex health interventions before a full-scale trial. Reporting followed the STROBE guidelines for observational studies.

Study Setting and Sampling

The study was conducted in the cardiothoracic surgery department of a large tertiary hospital in northern Portugal. Participants were adults aged ≥ 65 years scheduled for elective cardiac surgery, including valve replacement, coronary artery bypass grafting, or combined procedures. The recruitment goal was approximately 30 participants, consistent with methodological recommendations for feasibility studies, which emphasize small samples sufficient to evaluate processes, resources use, and preliminary outcomes (31). Participants were recruited consecutively according to surgery scheduling and availability.

Inclusion and Exclusion Criteria

Inclusion criteria were preserved cognitive function, registration for elective cardiac surgery and agreement to participate in the intervention and data collection.

Exclusion criteria were previous cardiac surgery, transplant, intraoperative device implantation during the index surgery (as the primary procedure), hemodynamic instability, inability to perform breathing exercises, or refusal to participate. All participants provided written informed consent prior to inclusion.

Study Intervention

Following referral by the surgeon, participants attended an initial in-person consultation with a Rehabilitation Nurse Specialist during routine service hours. The session focused on education and training in breathing and physical exercises, including diaphragmatic breathing, huffing, coughing with wound support, and progressive walking. Participants were also instructed on energy conservation strategies and posture optimization. Participants received a printed flyer and access to an instructional video demonstrating the exercises, and they were encouraged to involve a family member or caregiver during the session to facilitate understanding and support adherence to the program.

Participants were instructed to perform the exercises at least twice daily until hospital admission. Follow-up was conducted mainly by telephone or video call (at least once per week), with additional support available through email or messaging. The intervention aimed to ensure continuity of care, provide motivation, and allow early identification of difficulties or adverse symptoms.

A summary of the intervention content is presented in Textbox 1, and the educational flyer and instructional video link are available as supplementary material.

Instruments with Validity and Reliability

Data collection included sociodemographic and clinical variables, as well as validated and reliable instruments:

- Health-related quality of life was assessed using the EuroQol-5D (EQ-5D), a widely used measure that includes five dimensions—mobility, self-care, usual activities, pain/discomfort, and anxiety/depression, with scores reflecting perceived health status (32).
- Basic activities of daily living were evaluated using the Barthel Index, which assesses 10 functional tasks such as feeding, dressing, bathing, toileting, transfers, and ambulation. Total scores range from 0 (complete dependence) to 100 (complete independence) (33).
- Instrumental activities of daily living were measured using the Lawton Index, composed of eight items including telephone use, shopping, food preparation, housekeeping, laundry, transportation, medication management, and handling finances. Scores range from 0 (dependent) to 30 (independent) (34, 35).
- Health literacy was assessed using the HLS-EU, adapted and validated for Portuguese populations, which measures perceived ability to access and understand, appraise, and apply health information in everyday life (35).
- Exercise capacity was evaluated through the Six-Minute Walk Test (6MWT), conducted according to the American Thoracic

Society guidelines. The test was performed in a 30-meter indoor corridor under supervision by a rehabilitation nurse specialist. Participants were instructed to walk "*as far as possible*" in six minutes, and blood pressure, oxygen saturation, dyspnea, and fatigue (Borg's scale) were recorded before and after the test (36).

Participants were also asked to maintain a brief diary to record exercise sessions, perceived exertion, and any adverse events. Hospital length of stay was calculated from the day of surgery until discharge.

Data Analysis

Data were collected at two time points, at baseline (≥15 days before surgery) and at hospital discharge. Variables included clinical data, questionnaire scores (EQ-5D-3L, Barthel Index, Lawton Index and HLS-EU-PT scores) and 6MWT results. Follow-up continued until the last surgery in January 2023.

Missing values were handled through mean substitution when data were missing at random. Descriptive and inferential statistical analyses were performed using IBM SPSS Statistics 28.0®, applying parametric or non-parametric tests according to variable distribution.

Questionnaire-based outcomes (EQ-5D-3L, Barthel Index, Lawton Index and HLS-EU-PT) were scored according to their manuals to obtain total and, when applicable, domain scores. For the EQ-5D-3L, dimension responses were summarized into an index score and a visual analogue scale (EQ-VAS), with higher values indicating better perceived health status. For the HLS-EU-PT, item responses were recoded into total and domain scores (health care, disease prevention, and health promotion) and transformed into the standardized 0-50 health literacy index, in which higher scores reflect higher health literacy. Descriptive statistics (means, standard deviations, medians, interquartile ranges, and frequencies) were used to summarize sociodemographic, clinical and outcome variables. Pre- and post-changes in continuous outcomes (EQ-5D, Barthel Index, Lawton Index, HLS-EU-PT scores and 6MWT parameters) were analyzed using paired t-tests for normally distributed variables and Wilcoxon signed-rank tests for non-normally distributed variables. When applicable, pre-post changes in categorical variables were examined with McNemar's test. Effect sizes for pre-post differences were estimated using Cohen's *d*.

Ethical Considerations

The study was approved by the Research Ethics Committee (No. 49/2022) and by the Hospital Board (No. I28319-202406). The cardiac surgeon made the initial approach by briefly informing eligible

patients about the study and asking whether they were willing to receive more information. For those who agreed, a Rehabilitation Nurse Specialist was invited to provide a detailed explanation of the study's aims and procedures, answer questions, and verify eligibility. Patients were explicitly informed that their decision to participate or not would not affect their surgical scheduling or usual care. Data confidentiality and anonymity were guaranteed, and no financial incentives were provided.

Results

Sample Characteristics

The sample consisted of 30 participants, 19 (63.3%) men and 11 (36.7%) women, aged between 66 and 82 years (mean 74.27 ± 4.34 years). Most were married or living with a partner (60%), while 36.7% were separated, divorced, or widowed, and one (3.3%) was single. Twenty-six participants (86.7%) had children, with a mean of 1.83 ± 1.31 per participant, and 73.3% lived with another person, mainly a spouse (60%) or children (13.3%). All participants had attended school, with four years as the most frequent level of education and a mean of six years. All were retired, 28 (93.7%) by age and two (6.3%) due to disability.

The average distance from participants' homes to the hospital was 56.9 ± 62.3 km, ranging from 4 to 195 km. Regarding comorbidities, two participants (6.7%) reported claudication and other conditions included facial paralysis (1), osteoarticular disease (2), and spinal pathology (1). Concerning cardiovascular disease, 22 (73.3%) had previously undergone diagnostic percutaneous coronary intervention (PCI), four (13.3%) had suffered an acute myocardial infarction, and two (6.7%) had an implantable cardiac device prior to the index surgery. Two additional participants had undergone PCI without success, which led to the indication for elective surgery.

Nursing Consultation and Intervention Monitoring

During the first in-person consultation, each participant received a printed flyer describing the breathing exercises, which included a QR code linking to a YouTube instructional video. The video reached 26 views in total, 23 (88.5%) via mobile devices and three (11.5%) via computers. The total viewing time was 1 hour and 20 minutes, with 84.6% viewed on mobile devices and 15.4% on computers. The video lasted 4 minutes and 50 seconds, and the average viewing duration per user was 2 minutes and 44 seconds.

Throughout the waiting period for surgery, a total of 386 contacts were made between participants and the rehabilitation nurse specialist. Of these, 383 (99.2%) were teleconsultations and three

(0.8%) were face-to-face appointments. Among the teleconsultations, 338 (87.6%) occurred in real time, 335 (86.8%) via telephone and three (0.8%) in-person sessions at the hospital, while 48 (12.4%) were asynchronous, including 44 (11.4%) through text or WhatsApp® messages and four (1%) by email.

Participants listed for surgery under normal priority accounted for 251 (65%) of all contacts, averaging 12.9 ± 0.41 per person (range 1-30). Those with urgent priority represented 135 contacts (35%), averaging 23.9 per participant (range 2-30). The total duration of telephone consultations reached 3066 minutes (approximately 51.1 hours), with an average call length of 9.67 ± 8.82 minutes (range 1-90).

Adherence to the Intervention

Adherence to the exercise program was high. Eighteen (60%) participants performed the prescribed exercises twice daily, eight (26.7%) once daily, three (10%) occasionally, and only one (3.3%) did not adhere to the suggested plan.

Regarding walking practice, one participant (3.3%) reported walking 180 minutes daily, two (6.7%) for 90 minutes, eight (26.7%) for 60 minutes, three (10%) for 45 minutes, eight (26.7%) for 30 minutes, and the remaining for 10-25 minutes daily. Only one participant refused to walk.

When asked about other daily activities, 13 (43.3%) reported no additional physical activity, nine (30%) performed domestic tasks, four (13.3%) engaged in agricultural or field work, and four participants (3.3% each) reported distinct activities: one attended physiotherapy, one performed outdoor exercise, one assisted in a family business, and one managed their own enterprise.Complaints during exercise were rare and mainly related to transient discomfort or mild dyspnea; all were resolved by the rehabilitation nurse without requiring a hospital visit.

Self-Reported Practice Logs

Seven participants (23.3%) completed daily exercise logs. Among them, three (42.9%) completed sessions in under 15 minutes, two (28.6%) in under 30 minutes, one (14.3%) in under 60 minutes, and another one in under 90 minutes. Perceived exertion was classified as ‘very easy’ by five participants (71.4%), ‘easy’ by one (14.3%), and ‘moderately easy’ by another (14.3%).

Postoperative Information

Hospitalization ranged from four to eighteen days, with a mean stay of 7.2 ± 3.3 days. Sixteen participants (57.1%) underwent valve replacement, seven (25%) coronary artery bypass grafting, and five (17.9%) combined procedures.

Regarding surgical approach, seventeen (60.7%) underwent full median sternotomy, three (10.7%) mini-sternotomy, five (17.9%) "J" mini-sternotomy, and three (10.7%) mini-thoracotomy. Postoperative pulmonary complications (PPCs) were less frequent, 24 (85.7%) participants had none, one (3.6%) developed unilateral pleural effusion, and three (10.7%) bilateral pleural effusion. All PPCs were effectively managed without the need for reintervention or prolonged stay.

Participants without PPCs had an average hospital stay of seven days, while those with bilateral effusion stayed around 11 days.

Quality of Life Outcomes

The EQ-5D pre- and post-test results showed statistically significant improvement in the *usual activities* domain ($p<0.001$) and in the total EQ-5D score (mean pre-test = 5.37, post-test = 7.96; $p<0.001$). Other dimensions did not reach statistical significance.

Effect size analysis revealed small to medium effects for *mobility* ($|d| = 0.45$), *self-care* ($|d| = 0.37$), *usual activities* ($|d| = 0.43$), *pain/discomfort* ($|d| = 0.50$) and *anxiety/depression* ($|d| = 0.68$). Larger effects were found for the total EQ-5D score ($|d| = 1.64$) and EQ-VAS ($|d| = 16.90$).

Functional Status

According to the Barthel Index, a significant difference was observed in the *bed transfer* domain ($p=0.04$), suggesting improvement in mobility between pre- and post-test. Although other domains were not statistically significant, moderate to large effect sizes were found for *toileting* ($|d| = 0.64$), *dressing* ($|d| = 1.26$), *bathing* ($|d| = 0.90$), *bowel control* ($|d| = 0.91$), *bladder control* ($|d| = 2.09$), *stair climbing* ($|d| = 2.41$), *ambulation* ($|d| = 1.26$), and the total score ($|d| = 6.11$). These results reflect considerable functional gains after surgery and engagement with the preoperative intervention.

For instrumental activities, measured by the Lawton Index, participants were generally moderately dependent before surgery. Post-test results showed that 28 (93.5%) remained moderately dependent and two (6.7%) were severely dependent. Significant differences were found for *preparing meals* ($p<0.001$), *shopping* ($p<0.001$), and *handling finances* ($p=0.03$). Effect sizes ranged from small to medium ($|d| = 0.38$-0.75), with a large effect observed for *shopping* ($|d| = 3.20$), indicating notable postoperative limitation in this domain.

Health Literacy Outcomes

Pre-test HLS-EU-47 scores indicated limited or problematic health literacy (mean 32.4 ± 14.17), particularly in the *health promotion* domain. Post-test results revealed improvement in overall literacy (35.06 ± 13.01), reaching the threshold for sufficient literacy. The

health care and *disease prevention* dimensions showed the highest gains, whereas *health promotion* remained below the sufficient range. Although changes were not statistically significant, all dimensions exhibited large effect sizes (|d| > 0.8), suggesting a positive trend following the intervention.

Exercise Capacity Outcomes

The 6MWT results demonstrated significant differences in pre-test heart rate (p=0.02), dyspnea (p=0.003), fatigue (p=0.04), and post-test heart rate (p=0.05). Effect size analysis indicated large differences (|d| > 0.8) for most parameters, except for *technical aids* (|d| = 0.28), *stopped before six minutes* (|d| = 0.30), and *reason to stop* (|d| = 0.60). The total distance walked in six minutes did not differ significantly, suggesting preserved functional capacity at discharge.

Discussion

This feasibility study demonstrated that a preoperative e-Nursing intervention combining breathing exercises, education, and remote follow-up is both acceptable and feasible in terms of acceptability, adherence, safety, and preliminary clinical impact among older adults awaiting elective cardiac surgery. The high adherence rate, minimal adverse events, and positive participant feedback confirm the intervention's safety, acceptability and practical value. These findings reinforce the relevance of the rehabilitation nurse's role in guiding patients' preparation for surgery, not only by teaching physical exercises but also by promoting autonomy and self-management throughout the preoperative period.

The rarity of symptoms such as dyspnea or angina during exercise sessions, and the nurses' ability to assess and manage symptoms remotely, prevented unnecessary hospital visits and ensured safe participation. This is consistent with previous reviews reporting that remotely supervised exercise-based cardiac rehabilitation improves physical activity levels, reduces hospital readmissions, and enhances quality of life (38). These results highlight the growing importance of e-Health and nursing-led telemonitoring as effective strategies for maintaining continuity of care during surgical preparation.

Most participants underwent valve replacement, myocardial revascularization, or combined procedures, with the majority operated through full median sternotomy and a smaller number through minimally invasive techniques. The type of surgical approach influences the duration of recovery, the risk of postoperative complications, and even the patient's perception of cosmetic outcomes (39). Minimally invasive techniques have been associated with reduced drainage, shorter intensive care

and hospital stays, and faster functional recovery when compared with conventional sternotomy (23, 24, 40). The variability in surgical techniques among participants may therefore have contributed to differences in postoperative results and recovery trajectories observed in this study.

PPCs were rare, affecting only a small proportion of participants and resolving without the need for further intervention. This result supports existing evidence showing that preoperative respiratory training can reduce PPC risk by nearly half (29). However, most of these studies did not specify the surgical approach, making direct comparisons difficult. In this study, participants who developed PPCs had longer hospital stays (around 11 days) than those without complications (around 7 days), which reinforces the clinical relevance of early respiratory intervention in preventing functional decline and extended hospitalization.

Functional outcomes offered important insights into recovery. Although only the Barthel Index variable *bed transfer* reached statistical significance, the pattern of moderate-to-large effect sizes across multiple domains suggests that subtle improvements may not have been fully captured because assessments were conducted at discharge. Similarly, in the Lawton Index, increased dependence was observed in instrumental activities such as shopping and meal preparation. This trend is consistent with previous research indicating that functional limitations after cardiac surgery are common and influenced by both preoperative status and early postoperative restrictions (25, 26). From a rehabilitation perspective, these findings reinforce the importance of structured nursing interventions to promote early mobilization and progressive activity resumption as part of perioperative care.

In terms of exercise capacity, significant changes were identified in heart rate, dyspnea, and fatigue, with large effect sizes across most 6MWT parameters. However, the total distance walked did not differ significantly, indicating that global endurance was preserved. This maintenance of functional capacity may reflect the preventive effect of the preoperative intervention. Similar outcomes have been described in other studies where prehabilitation contributed to maintaining baseline performance and promoting smoother recovery (26, 41). The observed stability in performance suggests that the intervention may have mitigated postoperative functional decline, even if short-term improvements were not yet visible. These findings should, however, be interpreted with caution, as some participants presented conditions such as claudication (6.7%) and pre-existing osteoarticular or spinal disease, which may have influenced exercise performance and 6MWT outcomes, thereby affecting the observed effect size.

The timing of postoperative assessment likely influenced the results. Evaluations were conducted at discharge, a moment when patients are still recovering from surgery. Previous studies report that significant improvements in functional performance and quality of life are

more evident one month after surgery (42). Therefore, extending follow-up in future studies could help capture the longer-term effects of e-Nursing interventions on recovery trajectories.

Quality of life assessment showed significant improvement only in the *usual activities* domain, yet the overall EQ-5D scores presented large effect sizes, suggesting meaningful though early gains in daily functioning. The absence of significant change in *pain* or *emotional* domains can be explained by the proximity to discharge and residual discomfort typical of the postoperative period. These findings emphasize the need for continuity of rehabilitation and follow-up to consolidate gains and address emotional recovery.

Health literacy results revealed a positive progression from problematic to sufficient literacy in most dimensions, although differences were not statistically significant. This trend is encouraging, as limited health literacy is common among older adults and surgical patients (43, 44) which has been associated with increased postoperative complications (45). The improvement observed after the intervention indicates that structured educational strategies delivered by rehabilitation nurses can enhance understanding and self-management. By promoting health literacy, nursing interventions strengthen patients' capacity to participate actively in their care, adhere to recommendations, and recognize warning signs early.

Adherence to the intervention was high, confirming that older adults are receptive to technology-supported health education when guided by professionals. The combination of telephone and video follow-up contributed to maintaining motivation and adherence. Although the video was designed to support the intervention and promote health literacy, not all participants viewed it in full. This variability in engagement may be related to individual factors such as educational level or familiarity with digital tools, potentially influencing adherence and acceptability. Furthermore, two participants did not complete the study, these withdrawals were due to reasons unrelated to the intervention itself, namely a cancer diagnosis requiring prioritization of treatment and a decision not to proceed with surgery. Therefore, these cases do not appear to reflect issues with intervention acceptability. Evidence supports that e-Health interventions using telecommunication tools, such as phone calls, text messaging, and mobile applications, can improve adherence compared with traditional care (46-49). The positive engagement observed here demonstrates that digital nursing strategies can successfully complement conventional face-to-face rehabilitation, offering flexibility and continuity of care.

Overall, this study strengthens the case for integrating e-Nursing prehabilitation into routine cardiac surgical care. From a research perspective, the findings justify further investigation through larger randomized controlled trials to confirm effectiveness,

cost-efficiency and long-term outcomes. From an educational viewpoint, the results highlight the need to integrate preoperative rehabilitation, digital health, and remote monitoring competencies into nursing curricula. From a clinical standpoint, the feasibility demonstrated here confirms that simple breathing and mobility exercises supported by regular telemonitoring can be implemented effectively by rehabilitation nurses as part of standard preoperative care. Finally, from a policy and health systems perspective, such interventions can reduce postoperative complications, shorten hospital stays, optimize resources use and promote sustainability by reducing unnecessary travel and environmental impact associated with in-person appointments.

Conclusions

The findings of this feasibility study confirm that a preoperative e-Nursing intervention is both feasible and acceptable for older adults awaiting elective cardiac surgery. High adherence rates, low complication frequency, and improvements in health literacy demonstrate the value of structured, nurse-led prehabilitation programs. Although short-term changes in quality of life and functional performance were modest, the observed trends indicate positive potential for broader implementation.

Rehabilitation nurses are determinant in this process by guiding patients through preparation, exercise, and self-care, ensuring both physical and emotional readiness for surgery. Digital tools enhance their role, enabling continuity of care and active patient engagement beyond hospital walls.

Future research should include larger, controlled studies with extended follow-ups to evaluate the long-term effects and sustainability of e-Nursing interventions. Integrating prehabilitation into surgical care pathways may improve recovery, promote self-management, and contribute to more efficient and sustainable healthcare delivery.

Data Availability

Access to all data is granted upon request to the corresponding author.

Conflict of Interest

The authors declare no conflict of interest.

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Supplementary Material

Flyer outlining the preoperative exercises included in the e-Nursing intervention, featuring a QR code for accessing a YouTube video demonstration of these exercises.

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Textbox 1. Intervention Design

INTERVENTION DESIGN

1st Contact: In-person Specialized Nursing Consultation

Location: Room located in the inpatient area of the Cardiothoracic Surgery wards

Estimated consultation time: 45 to 60 minutes

Conducted by: Rehabilitation Nurse Specialist

Goals:

1. Earn the person's trust
2. Perform first nursing assessment
3. Evaluate the knowledge regarding surgery and health status
4. Train preoperative rehabilitation exercises, which should be started at least two weeks before surgery
5. Educate about warning signs and symptoms that can lead to the exercise's interruption
6. Educate on how to cough supporting surgical wound
7. Remember the importance of the exercises in the postoperative period
8. Discuss and emphasize the importance of therapeutic adherence
9. Provide technological means to clarify doubts asynchronously (phone number for messages and e-mail of reference nurse)
10. Schedule subsequent teleconsultation

2nd Contact: Real-time Specialized Nursing Teleconsultation

Communication technology: Telephone or, if possible, video call

Estimated consultation time: 15 to 30 minutes

Lead by: Rehabilitation Nurse Specialist

Subsequent contact: Weekly, until hospital admission or as needed (upon request by the individual, or if the nurse determines the need to reinforce education).

Goals:

1. Strengthen the person's trust
2. Evaluate the resolution of previously identified problems
3. Verify that the exercises were performed correctly and look for any concerns or symptoms that might have arisen
4. Encourage the performance of exercises
5. Continuously encourage therapeutic adherence
6. Resolve/reduce health problems
7. Plan subsequent teleconsultation

Deferred Contact: Deland-time Specialized Nursing Teleconsultation

Communication technology: Phone message, messaging application or email

Estimated consultation time: 15 minutes

Goals:

1. Check messages daily and respond