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Feasibility and effects of the telerehabilitation program during hematopoietic stem cell transplantation

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Abstract

This study aims to identify the feasibility and effects of the telerehabilitation program for patients with hematologic cancer who underwent hematopoietic stem cell transplantation (HSCT). In this single-arm prospective study, a telerehabilitation program was administered to patients who underwent HSCT. The program utilized a camera and video conferencing system, delivering 30-minute exercise sessions based on the Otago exercise. Baseline, immediate follow-up, and 3-month follow-up examinations were performed using the European Organization for Research and Treatment of Cancer Quality of Life Questionnaire 30, Beck Depression Inventory-II, fatigue severity scale, body composition, and a 10-item satisfaction survey. Fifteen (9 males and 6 females) completed the program. The mean number of exercise participation was 8.67 ± 1.91, and no adverse events or safety issues were reported. The results showed no significant deterioration in global health status, physical, role, emotional, cognitive, or social functioning as well as depression and fatigue. Physical function was well maintained without significant deterioration. In the satisfaction survey, participants believed that it was physically and mentally beneficial. This study showed that the telerehabilitation program may be helpful for patients undergoing HSCT. Direct communication with a physical therapist helped patients maintain their physical and mental health during isolation.

Abbreviations: EORTC QLQ-C30 = European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Core 30, FSS = fatigue severity scale, GCRD = Google Chrome Remote Desktop, HGS = handgrip strength, HSCT = hematopoietic stem cell transplantation, IPAQ-SF = International Physical Activity Questionnaire Short Form, QOL = quality of life, RCT = randomized controlled trial, SMM = skeletal muscle mass, VAS = visual analog scale.

Keywords: exercise, hematopoietic stem cell transplantation, physical activity, quality of life, telerehabilitation

1. Introduction

Hematopoietic stem cell transplantation (HSCT) is an effective treatment for hemato-oncologic malignancies involving high-dose chemotherapy and hospitalization.[1] The demand for HSCT has increased, resulting in improved survival rates and reduced morbidity. However, these procedures have physical and psychological side effects that can impact patients' quality of life (QOL).[2] During and after HSCT, patients experience adverse effects, such as infection, mucositis, diarrhea, and fatigue, leading to physical deterioration and emotional stress. These side effects interfere with their ability to cope with cancer and its treatment. Furthermore, patients often have difficulties returning to their social roles after HSCT.[2,3]

Although the efficacy of exercise programs among HSCT patients varies, several studies have shown positive effects on recovery of strength, physical activity, and performance.[4–8] For example, according to Abo et al, exercise improves functional exercise capacity, reduces fatigue, and decreases the length of hospital stay.[4] Additionally, exercise has been found to positively affect the recovery of QOL or fatigue after HSCT.[6,9,10] However, patients undergoing HSCT often showed low compliance with exercise programs because they experienced significant fatigue, nausea, vomiting, muscle loss, and impaired physical function.[2] In addition, severe marrow suppression increases bleeding, infection, and anemia risks.[3,5] In particular, group training or exercise outside the isolation ward is impractical because of the risk of infection and deteriorated conditions, necessitating individualized programs. Regular visits by specialists may motivate patients to exercise; however, the risk of infection due to contact between the therapist and patient remains.

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Key points

- The study results demonstrated that telerehabilitation can be beneficial in preventing fatigue, depression, decreased quality of life, and physical function decline in patients with HSCT.
- Conventional rehabilitation, being conducted in person, can potentially exclude isolated patients for reasons such as infection or compromised immunity, resulting in their marginalization from the treatment process.
- Telerehabilitation shows promise in addressing these challenges.

Telerehabilitation has been suggested as an alternative to in-person rehabilitation therapy.[11] Telehealth, including telemedicine, has gained significant traction during the coronavirus disease 2019 pandemic, especially for at-risk populations such as patients with cancer.[12,13] Telerehabilitation utilizes technology to provide remote personalized healthcare, enhancing access to professional care and overcoming immune risks. It has shown feasibility, acceptability, and effectiveness in improving daily participation, QOL, functional abilities, and symptom management in cancer survivors.[12,13] It offers benefits such as decreased travel time and access to specialized cancer rehabilitation services.[11,14] Telerehabilitation allows cancer survivors to exercise conveniently and at their own pace, improving outcomes, and reducing pain and hospital stays. Telerehabilitation via platforms, such as Zoom or Skype, has been comparable to in-person rehabilitation and has received high satisfaction levels from participants.[15] A review of telehealth-based exercise interventions in cancer survivors reported high compliance, symptom relief, and no adverse events.[16] Recently, a systemic review showed that numerous studies evaluating telehealth-based exercise interventions in cancer survivors, involving over 3600 participants, have reported high patient compliance and no adverse events.[17] Another recent quantitative and qualitative study on 123 cancer survivors has also described that telerehabilitation is safe and feasible and improves outcomes.[16] Therefore, telerehabilitation may be valuable in patients with HSCT undergoing isolation treatment. However, no study has targeted patients with rapidly degrading physical and mental conditions, such as patients with HSCT.

Therefore, this study aimed to evaluate the feasibility, safety, and accessibility of a telerehabilitation program for HSCT patients. We assessed how many patients were able to participate and continue their participation, whether there were any side effects from participating in the program, and if there were any difficulties using the communication program. Furthermore, we also analyzed its impact on physical and psychological status and quality of life for future studies.

2. Materials and methods

2.1. Participants

From September 2021 to February 2023, adults aged 20 to 75 years diagnosed with hematologic malignancies and planning to undergo bone marrow transplantation were recruited for this study (Fig. 1). The exclusion criteria were as follows: individuals who (1) had musculoskeletal disorders and neurological conditions that hindered exercise performance, (2) had a history of cardiovascular diseases and were undergoing treatment, (3) had visual or hearing impairments that made remote rehabilitation exercise therapy challenging, (4) were taking medication for mental disorders such as depression and insomnia, and (5) were unable to participate in the exercise program for other reasons. The Ulsan University Hospital Institutional Review Board approved this study protocol (UUH 2021-07-017). This trial was registered with the Clinical Research Information Service (KCT0006487).

2.2. Telerehabilitation system

A telerehabilitation system for the patients consisted of Zoom video conference software (Zoom Video Communications, Inc., San Jose, CA), a television monitor, an operating computer, and a BCC 950 video conference camera (Logitech, Lausanne, Switzerland). These systems were prepared and installed in four patient rooms in the isolation ward (Fig. 2). For the physiotherapist, a similar telerehabilitation system was built in our rehabilitation center, distant from the isolation ward. In addition, to minimize inconvenience for patients and ward nurses, Google Chrome Remote Desktop (GCRD) was utilized. GCRD is a Google Chrome browser extension program that allows a Google account user to access other computers through Chrome (Google, Mountain View, CA) and freely use the software on a remote computer. In this study, the physiotherapist remotely accessed the patient's computer and operated the Zoom software using GCRD. Therefore, the patients did not have to manipulate the computer or Zoom software during the exercise session. Immediately after the ward nurse turned on the computer at the designated time, the physiotherapist remotely operated the computer, started the Zoom software on the patient's computer, and completed the screen composition for exercise within 5 minutes. While the physiotherapist prepared, the participants just sat before the monitor and waited. When preparation was completed, ward nurses stood at the ward station for emergencies or help.

The monitor screen comprised 3 small windows: a window for the prerecorded exercise guide video and 2 real-time video windows for the physiotherapist and patient (Fig. 3). First, the physiotherapist greeted the patient, checked the patient's condition, and explained the exercise program of the day. A recorded movie demonstration was shown for each exercise, and the physiotherapist explained how to perform the exercises. The patient performed each exercise following the physiotherapist's instructions. The physiotherapist also provided verbal and visual feedback about the patient's real-time movements and checked for discomfort during the training. Patients could also check their movements by watching their real-time windows on the monitor. When each exercise session ended, the therapist shut down the Zoom software and computer using GCRD. The novelty of this study lies in the implementation of telerehabilitation in the isolation ward environment using a remote-control program, without requiring any patient manipulation. Both the remote-control program and the video conference software can be easily downloaded and used for free from the internet.

2.3. Exercise program

A specialized oncology physiotherapist administered the individualized rehabilitation program. The program was started on the day of HSCT admission or the following day. The exercise program was based on the "Otago exercise" program, which focuses on light strength, flexibility, and balance exercises for the elderly.[18] The Otago exercise program is a well-designed program aimed at improving strength and balance to reduce falls, and clinical trial results have shown it to be effective in reducing falls for independently living older individuals. Additional exercises were incorporated, as some patients may be capable of performing higher-intensity exercises. The program consisted of aerobic, stretching, and strengthening exercises. Approximately 2-min instructional videos were prepared for each exercise. The exercise program was primarily designed to be performed safely on a bed or chair. For strength training,

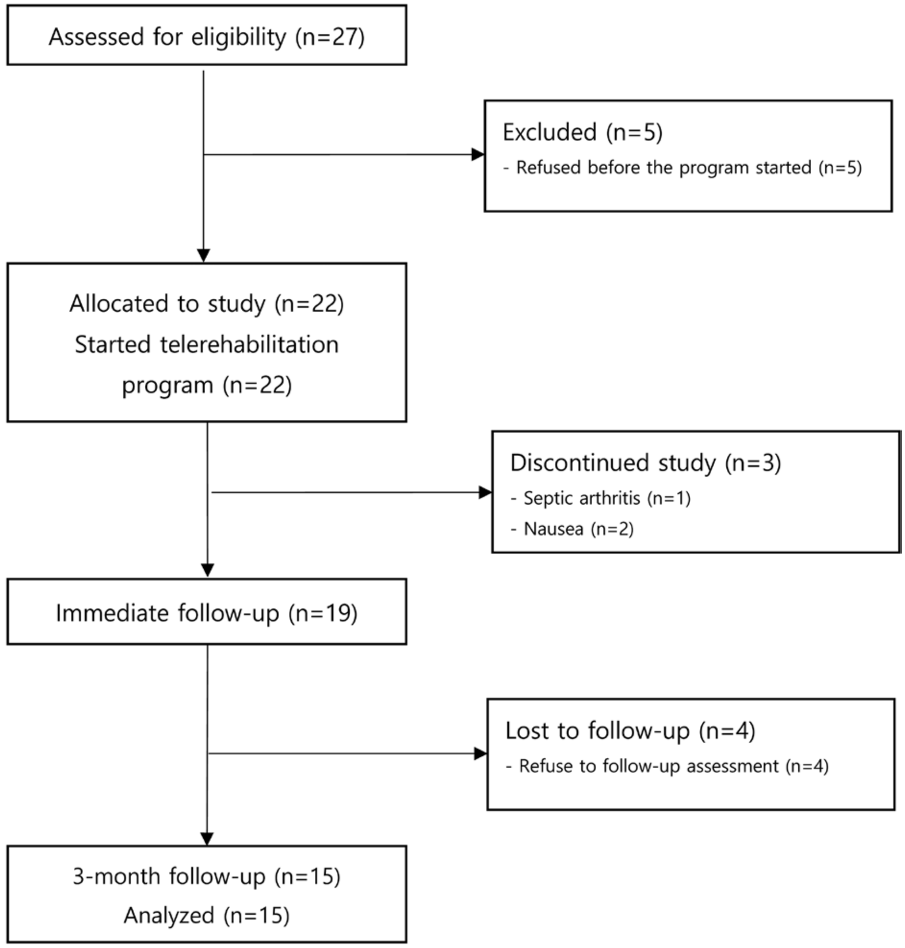

Figure 1. CONSORT flow diagram.

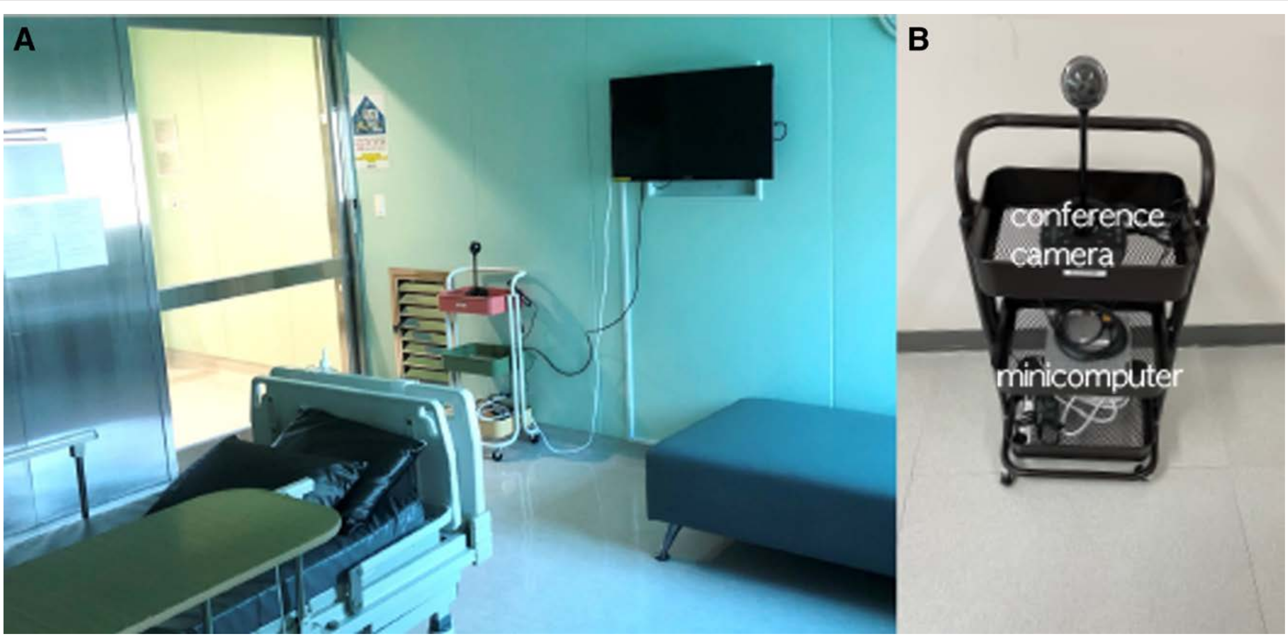

Figure 2. Telerehabilitation program setting in an isolated patient room. A conference camera and minicomputer for the telerehabilitation program in a three-tier rolling cart.

dumbbells or therapeutic bands were used. Before starting the exercise, the oncologist confirmed the patient's condition for the day as well as the blood test results and the patient's willingness to participate. The exercise was then performed, and approximately 30 minutes were allocated for 1 session. Since the participants' exercise abilities and needs are expected to vary. the

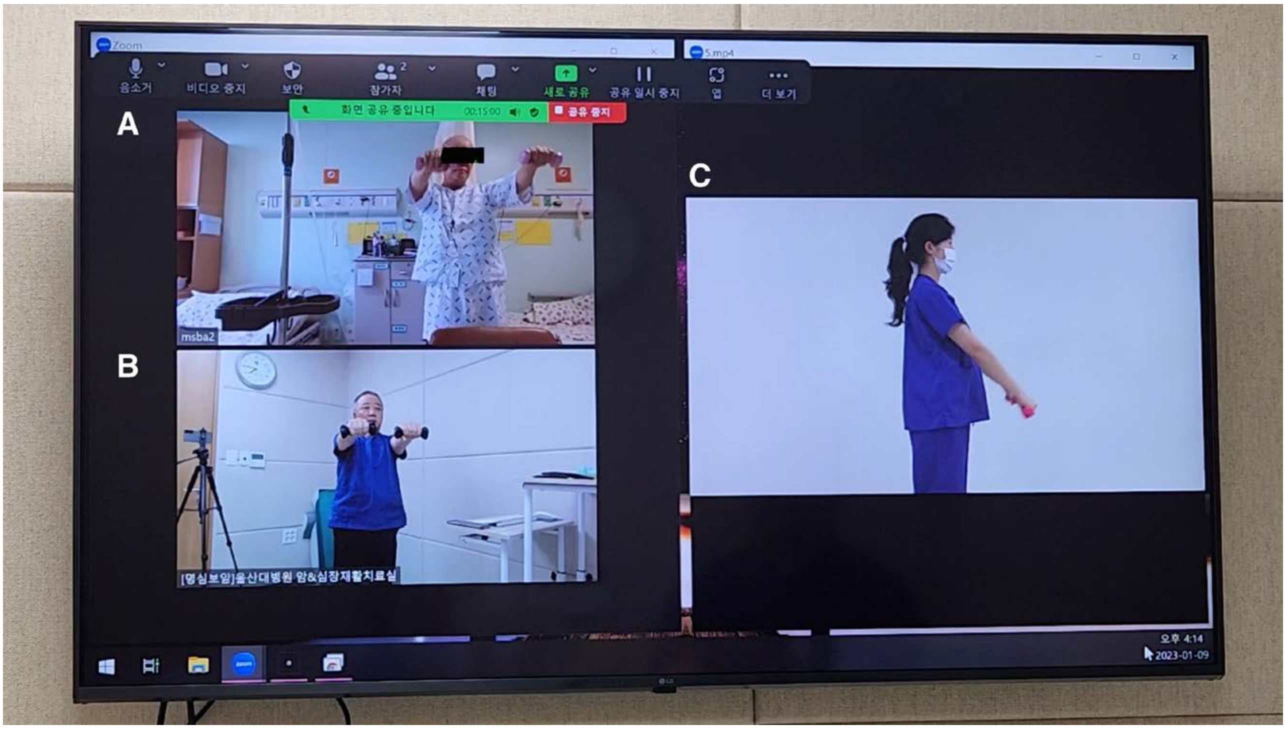

Figure 3. Composition of the monitor for the telerehabilitation program: real-time video window for the participant (top left), real-time video window for the physiotherapist (bottom left), and window for the prerecorded exercise guide video (right). Informed consent was obtained from the patient for publication of this case report details.

experienced therapist continuously monitored the patient's condition and adjusted the intensity in real-time. Unlike artificial intelligence-based programs that provide exercises for a limited number of situations,[19] we aimed to provide an individualized exercise program that stays within a safe range as much as possible.

2.4. Assessments

Evaluations were conducted just before admission to the isolation ward, immediately after discharge from the ward, and in the third month after HSCT. Initially, clinical data were collected, and the level of physical activity over the past week was investigated using the International Physical Activity Questionnaire Short Form (IPAQ-SF) at the baseline and 3-month follow-up.[20] The changes in QOL, fatigue, pain, depression, and physical and functional status were assessed from baseline to follow-up. Additionally, a satisfaction survey regarding the telerehabilitation program was conducted upon discharge from the isolation ward.

2.5. QOL, fatigue, pain, and depression

The European Organization for Research and Treatment of Cancer Quality of Life Questionnaire Core 30 (EORTC QLQ-C30) is the most widely used assessment tool for QOL in cancer research and practice.[21] The EORTC QLQ-C30 consists of 30 items, including 5 functioning scales (physical functioning, social functioning, role functioning, emotional functioning, and cognitive functioning), 9 symptom scales (fatigue, pain, nausea/vomiting, dyspnea, sleep disturbances, appetite loss, diarrhea, constipation, and financial difficulties), and a global health status/QOL scale. It is a 100-point scale, with higher scores indicating a better QOL. The validity and reliability of the Korean version were confirmed.[22] The Korean version of the fatigue severity scale (FSS) was used to evaluate the severity of fatigue.[23] The FSS is a self-report questionnaire describing the fatigue levels of the previous week. The FSS consists of 9 items on a Likert-type scale of 1 to 7 points.[24] Visual analog scale (VAS) is a widely used tool to measure pain intensity. The VAS is often expressed as a horizontal line approximately 10 cm long, with words or expressions at either end indicating "no pain at all" and "worst pain."[25] Individuals subjectively mark the area corresponding to their pain level on the line. The Korean version of the Beck Depression Inventory-II was used to evaluate the degree of depression.[26] It consists of 21 groups of questions that reflect how the individuals feel the past 2 weeks.

2.6. Physical and functional status

Weight, body mass index, skeletal muscle mass, and percent body fat were measured using the InBody S10 body water analyzer (InBody, Seoul, Korea). Physical strength was evaluated based on the handgrip strength (HGS). The HGS is a crucial method for assessing general muscle strength. The maximum HGS was measured using a handheld dynamometer (*Saehan* Corporation, MSD Europe, BVBA, *Belgium*) with the elbow bent at 90° from the sitting position. The HGS task was repeated thrice, alternating between the right and left sides. The 6-min walk test is a widely used assessment tool for evaluating aerobic capacity. This test measures walking ability and endurance.

2.7. Satisfaction survey

A purpose-designed participant satisfaction survey consisting of 10 questions related to effectiveness, convenience, and level of satisfaction was completed at the end of the exercise program. Of the 10 responses, 8 were recorded on a 5-point Likert scale. However, 2 questions about the type of exercise that was most satisfactory and the type that needed reinforcement were selected using a three-choice method.

2.8. Statistical analysis

The Statistical Package for Social Sciences version 24.0 was used for statistical analysis. The Kolmogorov–Smirnov test was used to test the normality assumption, and variables were distributed normally, except for the EORTC QLQ-C30, FSS, and IPAQ-SF. *Repeated-measures analysis* of *variance* with *Turkey* post hoc test was applied to determine changes in parametric variables. A *nonparametric Friedman test* was performed followed by a *post hoc Wilcoxon signed-rank test*. The IPAQ-SF was only surveyed at baseline and at the 3-month follow-up; therefore, the *Wilcoxon signed-rank test* was used for the analysis. Interpretations were made for data with a *P*-value of ≤.05, which was considered statistically significant.

3. Results

Initially, 27 participants were enrolled and 15 completed the program and follow-up assessments. Among the 12 dropped individuals, 5 refused participation before the program started, and 3 could not complete the program because of medical problems or worsening conditions during HSCT. Another 4 completed the telerehabilitation program but refused follow-up assessment after 3 months. The characteristics of the 15 participants are listed in Table 1. The mean age of all participants was 52.2 ± 6.8 years, and 9 (60.0%) were male. Eight participants (53.3%) underwent allogeneic HSCT. The most common type of cancer was acute myeloid leukemia, which affected 5 patients (33.3%). The mean length of the admission period was 19.53 ± 1.77 days, and the mean number of participated sessions was 8.67 ± 1.91. The participants' conditions were regularly monitored during the exercise sessions. No serious adverse events or complaints of discomfort were noted after the exercise sessions.

First, the study results showed no significant changes in QOL as measured by the EORTC QLQ-C30. The global health status and QOL score slightly decreased after the isolation period but recovered at the 3-month follow-up. Analysis of the functional subscales of the EORTC QLQ-C30 showed no significant deterioration; however, a tendency for decreased physical functioning was observed (*P* = .052). In addition, most symptom scales showed no significant decline except for the dyspnea scale score. Dyspnea worsened significantly at the 3-month follow-up, whereas no significant difference in scores was noted between baseline and the first follow-up after HSCT. Additional post hoc analysis of dyspnea showed significant worsening at the 3-month follow-up compared to baseline (*P* = .035).

Second, Beck Depression Inventory-II results showed no significant deterioration in depression after HSCT. Most participants were not depressed at baseline, and their mood remained good until the 3-month follow-up. The FSS and pain VAS results also showed no considerable worsening of the fatigue or pain. Additionally, the fatigue and pain subscales of the EORTC QLQ-C30 showed no significant changes. Therefore, this telerehabilitation program demonstrated the potential to prevent the aggravation of fatigue and pain symptoms and to induce positive changes in mood status.

Third, comparisons of physical status between baseline and follow-up are presented in Table 2. No significant changes were noted in weight, body mass index, skeletal muscle mass, percent body fat, or HGS. In particular, muscle mass and strength were well maintained until the 3-month follow-up. Therefore, the results showed that the exercise program prevented deterioration in body composition and muscle strength immediately after transplantation and for up to 3 months. In addition, participants' physical activity levels and patterns were assessed using the IPAQ-SF at baseline and at the 3-month follow-up. However, the results showed that the physical activity level at the 3-month follow-up was lower than that at baseline. Vigorous and moderate physical activity levels decreased further.

Finally, the satisfaction survey results presented high overall satisfaction with the telerehabilitation program on a 10-point numeric rating scale (8.20 ± 2.34). Furthermore, participants rated the exercise program as physically and mentally beneficial on a 5-point Likert scale (4.20 ± 1.15) (Table 3). Participants believed that communicating with the physiotherapist via the Zoom video conference program was neither complex nor uncomfortable. Additionally, the participants strongly recommended this exercise program to other transplant patients (4.07 ± 0.80). These findings showed positive feedback and overall satisfaction with this telerehabilitation program, supporting the feasibility and value of the program for patients undergoing HSCT. However, contrary to our predictions, participants felt that the exercise intensity was relatively low and the 30-min exercise duration was short. For similar reasons, half of the participants suggested reinforcing the strengthening exercises in our telerehabilitation program.

4. Discussion

To the best of our knowledge, this is the first study to apply telerehabilitation to patients with hemato-oncologic cancer undergoing HSCT in an isolated hospital ward setting.

Table 1

General characteristics of participants.

	N = 15
Age (years)	52.2 ± 6.88
Sex (male:female)	9:6
Marital status	
Married	15
Education level	
Elementary school	1
Middle school	2
High school	8
University	4
Smoking	
Former smokers	8
Nonsmokers	7
Alcohol	
Nondrinkers	9
Drinkers	4
Abstainers	2
Height (cm)	163.71 ± 7.63
Weight (kg)	67.09 ± 9.01
BMI (kg/m^2)	25.10 ± 3.27
Cancer type	
Acute myeloid leukemia	5
Diffuse large B-cell lymphoma	3
Angioimmunoblastic T-cell lymphoma	2
Acute lymphoblastic leukemia	2
Myelodysplastic syndrome	1
Follicular lymphoma	1
Multiple myeloma	1
Chemotherapy regimen	
BuCyE	5
BuFluATG	7
BuE	1
BuEAM	1
HD-MEL	1
Transplant	
Allogenic	8
Autologous	7
Isolation period (days)	19.53 ± 1.77
Number of telerehabilitation treatment	8.67 ± 1.91

Values are mean ± standard deviation.

BMI = body mass index, BuCyE = busulfan, cyclophosphamide and etoposide, BuE = busulfan, etoposide, BuEAM = busulfan, etoposide, cytarabine, melphalan, BuFluATG = busulfan, fludarabine, and antithymocyteglobulin, MD-MEL = high-dose melphalan.

Table 2

Changes in physical and psychological status between pre- and post-intervention.

	Baseline	Follow-up after transplant	Follow-up after 3 months	*P*-value
Physical status				
Weight (kg)	67.09 ± 9.01	65.16 ± 8.30	65.15 ± 9.29	.604
Body mass index (kg/m^2)	25.1 ± 3.27	24.44 ± 3.26	24.31 ± 3.01	.982
Skeletal muscle mass (kg)	25.79 ± 4.83	24.87 ± 4.64	24.39 ± 5.79	.256
Percent body fat (%)	29.2 ± 8.92	29.13 ± 9.43	30.51 ± 10.56	.742
Hand grip strength (kg)				
Right hand	33.37 ± 9.30	30.77 ± 9.77	30.2 ± 9.71	.925
Left hand	29.17 ± 8.86	27.01 ± 8.32	29.11 ± 9.17	.815
EORTC QLQ-C30				
Global health status/quality of life	69.27 ± 22.28	62.20 ± 17.05	68.33 ± 18.70	.212
Function scales				
Physical functioning	85.33 ± 16.75	78.13 ± 11.53	76.00 ± 17.01	.052
Role functioning	82.27 ± 22.23	80.00 ± 22.88	75.73 ± 24.17	.749
Emotional functioning	85.53 ± 16.55	85.60 ± 15.57	85.60 ± 15.57	.911
Cognitive functioning	92.20 ± 12.34	88.87 ± 13.53	90.00 ± 13.72	.641
Social functioning	71.13 ± 21.35	72.40 ± 17.41	71.20 ± 17.17	.629
Symptom scales/items				
Fatigue	22.07 ± 18.30	31.67 ± 16.29	33.13 ± 15.25	.130
Nausea and vomiting	9.93 ± 15.04	23.27 ± 5.02	13.40 ± 21.92	.061
Pain	16.67 ± 19.90	14.53 ± 18.79	17.93 ± 17.23	.739
Dyspnea	15.40 ± 17.04	17.67 ± 21.28	28.67 ± 17.20	.038*
Insomnia	17.67 ± 21.28	28.80 ± 30.55	22.13 ± 24.15	.239
Appetite loss	17.73 ± 24.81	28.80 ± 24.85	24.33 ± 23.48	.535
Constipation	13.20 ± 16.73	24.27 ± 19.74	11.00 ± 16.10	.199
Diarrhea	13.27 ± 21.05	31.00 ± 23.55	13.20 ± 16.73	.075
Financial difficulties	26.60 ± 25.90	26.60 ± 31.41	31.00 ± 34.44	.829
BDI-II	10.13 ± 7.13	11.47 ± 7.63	11.33 ± 9.12	.882
Fatigue severity scale	23.67 ± 13.31	25.27 ± 12.51	25.07 ± 12.41	.819
Pain visual analogue scale	3.20 ± 2.34	3.33 ± 1.88	3.20 ± 2.70	.793
International Physical Activity Questionnaire–Short Form				
Vigorous (min/day)	78.00 ± 162.67	-	41.33 ± 100.34	.865
Moderate (min/day)	56.00 ± 110.44	-	71.33 ± 94.63	.541
Mild (min/day)	351.33 ± 371.15	-	344.67 ± 268.64	.712
Time spent sitting (min/day)	314.00 ± 173.03	-	263.33 ± 194.70	.183

Values are mean ± standard deviation.

* $P < .05$ is statistically significant.

BDI-II = Beck's depression inventory-II, EORTC = European Organization for the Research and Treatment of Cancer Quality of Life Questionnaires, EORTC QLQ-C30 = European organization for research and treatment of cancer quality of life questionnaire core 30.

Table 3

Results of the satisfaction survey.

	Mean ± SD
1. Was the exercise program you participated in physically and mentally beneficial?	4.20 ± 1.15
2. Was the overall exercise intensity of the provided exercise program appropriate for you ("very low" is 1, "very strong" is 5)?	2.87 ± 0.35
3. Was the exercise duration (20–30 minutes) of the provided exercise program appropriate ("very short" is 1, "very long" is 5)??	2.73 ± 0.46
4. Was participating in the exercise program interesting?	3.47 ± 0.99
5. Did you communicate well with the physical therapist?	4.00 ± 0.85
6. Which type of exercise was most beneficial to you?	N = 15
Aerobic exercise	1
Stretching exercise	10
Strengthening exercise	4
7. Which type of the exercise do you want to strengthen a little more?	N = 15
Aerobic exercise	4
Stretching exercise	3
Strengthening exercise	8
8. Would you recommend this program to other transplant patients?	4.07 ± 0.80
9. After participating in this study, did you feel motivated to continue exercising in the future?	3.87 ± 0.99
10. How would you describe your satisfaction with the remote exercise program on a scale of 0 to 10?	8.2 ± 2.34

The results demonstrated that the telerehabilitation program was feasible and highly satisfactory for patients undergoing HSCT. Additionally, it contributed to maintaining the quality of life, as well as reducing feelings of depression and fatigue, while supporting physical status and function among patients. Consequently, telerehabilitation could serve as a valuable supplement to the conventional in-person treatment for HSCT patients requiring isolation and careful observation due to infection or deteriorating physical and mental conditions.

Recently, telerehabilitation technology has been continuously evolving, and various technologies are currently being utilized for diagnosis, treatment, and prevention in telerehabilitation. Technologies such as video conferencing, phone calls, smartwatches, and mobile applications have commonly been used.[27] Virtual or augmented reality and various sensor devices are also being tested.[17] However, patients inevitably encounter difficulties due to the complexity of the technology.[28–30] Notably, in the case of patients with hemato-oncologic cancer, who are often elderly, operating unfamiliar technologies can be burdensome, especially when isolated in physically and psychologically stressful circumstances. Therefore, we have made several efforts to solve these problems and increase their feasibility. First, we implemented a remote-control system to enhance affordability and ensure user-friendliness. Using the GCRD remote-control system, the physiotherapist can control the patient's computer and software programs without the help of the patient and nurse. Thus, the patients or ward nurses did not need to learn how to use the system; therefore, the patients could easily focus on the exercise. Recently, Mukaino et al also showed high patient satisfaction by applying a remote-control program in patients isolated from coronavirus disease 2019 infection.[15]

Second, in this study, physiotherapists were attempted to pay more attention to patient monitoring and feedback for individualized intervention. Issues regarding the lack of audio/visual feedback or fidelity were raised in previous studies on telerehabilitation.[16] Dissatisfaction with the appropriateness of this feedback was also observed in earlier studies of telerehabilitation programs using artificial intelligence.[19] Indeed, video conferencing can be better than communication only through voice or text; however, it is inevitably inferior to face-to-face rehabilitation.[31] In the traditional face-to-face rehabilitation treatment, therapists can guide movements directly using their hands and body while simultaneously monitoring the patient's movement. This allows for a safer exercise environment and the immediate correction of incorrect or unsafe movements. However, in the case of telerehabilitation, ensuring safety and movement accuracy becomes challenging as therapists can only rely on visual and audio cues.[31] At times, the physiotherapist also finds it challenging to monitor the screen depending on posture.

This may cause serious safety issues, and telerehabilitation could also burden physiotherapists. Therefore, we divided the screen into 3 parts: 1 for the patient, 1 for the therapist, and 1 displaying a prerecorded video demonstrating the movements. While the patient could perform the movements by following the guide video, the physiotherapist checked the patient's movements and provided appropriate feedback. This setup allowed the therapist to focus more on observing the patient's movements and providing feedback, ensuring smoother communication, and increased patient safety. As a result, the satisfaction survey also showed high satisfaction with communication with the therapist, and no adverse events were reported. By implementing the 2 methods described earlier, we aimed to reduce patients' resistance and discomfort toward telerehabilitation while ensuring its safety, thereby enhancing its overall feasibility.

Next, regarding the interpretation of the research results, this study measured changes in the participants' QOL, as well as their physical and psychological status. As the study design was not a randomized controlled trial (RCT), it was difficult to clearly show a significant effect on physical and mental status. However, QOL, body composition, and psychological and physical status were well maintained for up to 3 months after transplantation. Generally, QOL decreases immediately after HSCT.[5] Exercise is often beneficial for the physical and mental conditions and QOL in patients with cancer,[32–34] and several previous studies have also already reported beneficial effects on patients with hemato-oncologic cancer undergoing transplantation.[4,6,33,35] After HSCT, it takes months or even years for QOL to recover to prior states.[36–38] Several RCTs have reported that exercise helps restore QOL in transplant patients.[4,8,39] However, these studies were mainly conducted after transplantation rather than during HSCT. Wiskemann et al attempted an exercise program for approximately 16 weeks before, during, and after HSCT, and the results showed a significant improvement in the EORTC physical function score compared with that in the control group.[8] However, the improvement was observed only at the follow-up of 6 to 8 weeks after transplantation; instead, a decrease in the overall EORTC score was observed in both the experimental and control groups at the time of discharge after transplantation. Therefore, the results of this study, which demonstrated well-maintained EORTC scores during HSCT, may highlight the feasibility of telerehabilitation as a supportive intervention for maintaining QOL. However, to determine the exact effectiveness, further controlled studies are required.

In addition, several previous RCTs have reported that exercise before and after transplantation improves fatigue and physiologic well-being.[9,40,41] In this study, the levels of fatigue and depression before and after HSCT were also well maintained without significant deterioration. However, it was difficult to expect a significant improvement because the baseline levels of fatigue and depression were already low. However, it appeared well maintained during transplantation and follow-up, indicating the benefit of the telerehabilitation program. Unlike other cancers, patients with hemato-oncologic cancer undergoing HSCT, especially isolation with limited contact with family members, can induce psychological stress.[42] Communication with the therapist through exercise appeared to help overcome these difficulties and maintain a positive mindset. Furthermore, telehealth is expected to be used in various ways for mental support in that it can enable communication with the physiotherapist and psychotherapists or family members, regardless of place or time.[11,43]

In addition, the telerehabilitation program helped maintain physical status and function during HSCT. Similar to psychological status or QOL, a decrease in physical or functional level due to HSCT is often observed,[2,44] and previous studies have shown that active physical activity had beneficial effects on preventing this deterioration and helping functional recovery.[4,7,8,39,45] However, most studies have provided exercise programs before or after the isolation phase. Telerehabilitation could provide continuous exercise during HSCT isolation. In particular, telerehabilitation may be attractive, because it reduces the risk of infection. It can be performed on the bed in the patient's room under the observation of the hemato-oncologic staff. However, because this study was not comparative, it was difficult to determine the significance of the results. Therefore, the authors plan to perform a controlled study with more participants in the future.

This study has several limitations. First, exercise intensity did not reach the recommended levels because of safety concerns. Consequently, some patients complained that higher-intensity strengthening exercises may be more effective. More than we expected, patients tolerated HSCT well and remained physically fit. Hence, if a secure environment could be established, higher-intensity levels could be applied based on the patient's condition. Furthermore, the limited space in the patient rooms posed challenges for using equipment such as treadmills or bicycles. Considering the lower risk of falls and less space occupied, the bike is expected to be helpful as a device that can adjust the exercise intensity according to the patient's ability. Additionally, this study did not identify any adverse effects associated with telerehabilitation, which may be attributed to the low exercise intensity.

Second, motivation for exercise only at times translates into increased exercise levels after discharge. The post-participation survey results indicated that the participants felt motivated to continue exercising following HSCT. However, at the 3-month follow-up, participation in moderate-intensity activities slightly decreased.

This outcome underscores the importance of ongoing education and exercise programs after transplantation. Although active physical activity during the transplantation phase is crucial within feasible limits, we believe that education on regular exercise and inducing participation is necessary, even before HSCT. It is also essential to ensure that this effort extends seamlessly into the transplantation and posttransplantation periods.[8,46] As the previously cited study by Wiskemann et al indicated, it is noteworthy that engaging in exercise both before and after transplantation demonstrated a high adherence rate of 90%.[46] This suggests the significance of exercise engagement across the transplant continuum. Future studies should consider the broader application of telerehabilitation, encompassing the pretransplantation and posttransplantation periods. However, significant worsening of dyspnea was also observed in the EORTC QLQ-C30 at the 3-month follow-up, which may also hinder the patients from participating in active exercise at this time. Particularly within the first 3 months, occurrences such as infections, chemotherapy-induced lung injury, and idiopathic pneumonia syndrome are known to be observed, suggesting these as potential causes for the exacerbation of dyspnea.[47] These medical problems may have lowered exercise motivation.

Finally, the number of participants in this study was small. This was because of the challenges of cancer treatment, leading to a high dropout rate and strict eligibility criteria, resulting in a small sample size. In this study, patients with musculoskeletal conditions were excluded to avoid confounding the effects of exercise, and patients receiving cardiovascular treatment were also excluded to ensure safety. These strict criteria may be another reason for the absence of adverse effects mentioned earlier in this study. Furthermore, a single-arm study design was used to evaluate the effectiveness of telerehabilitation without a control group. However, the need for a control group in the study design limits its ability to differentiate the effects of telerehabilitation from other factors. In future research, we plan to conduct a randomized controlled trial that includes a control group to study the effectiveness of telerehabilitation in HSCT patients.

5. Conclusion

In conclusion, this study demonstrated that the telerehabilitation program was safe and easily accessible to HSCT patients. Unfortunately, approximately half of the participants discontinued due to worsening medical conditions. However, we thought this result showed the necessity of the active exercise program before HSCT. And we thought our telerehabilitation could serve as an effective alternative approach. Furthermore, the results also suggested that telerehabilitation might have a positive impact on maintaining physical function and QOL, while also reducing depression and fatigue without deterioration. Thus, given the growing need for exercise in isolated conditions, it would be worthwhile to conduct larger studies in the future.

Author contributions

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