**Title: Study Protocol for Comparison of Postoperative Telerehabilitation and Unsupervised Home-Based Training in Older Adults with Lung Cancer: A Randomized Controlled Trial**

**NCT Number: NCT05435885**

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***STUDY DESIGN***

This was a multicenter, parallel-group, RCT with concealed allocation and assessor blinding. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study was approved by the Institutional Review Boards of Pusan National University Hospital (2205-033-114) and Pusan National University Yangsan Hospital (05-2022-143) and was registered with ClinicalTrials.gov (NCT05435885). All participants provided written informed consent.

***SETTING AND PARTICIPANTS***

Patients aged ≥ 65 years with lung cancer scheduled for VATS were recruited. The exclusion criteria included patients with limited ambulation requiring an assistive device due to musculoskeletal disorders or cerebral infarction, those with implanted medical devices, individuals unable to use mobile messenger applications, and those participating in other clinical trials assessing exercise capacity.

***SAMPLE SIZE AND RANDOMIZATION***

The sample size was calculated using G*Power (version 3.1.9.6) based on an estimated between-group difference in $VO_2$peak of 3.4 mL/kg/min after the intervention. This estimate was derived from previously published data, where the post-intervention $VO_2$peak values were 23.3 mL/kg/min in the exercise group and 19.0 mL/kg/min in the control group.[18] A power analysis using an effect size of 0.74, a significance level of 0.05, and power of 0.80 determined the required sample size. Based on a power analysis, the required number of participants was 60. To account for an anticipated dropout rate, we screened 96 patients. A total of 64 participants were ultimately randomized. Participants were randomly assigned 1:1 to an intervention group (IG) or a control group (CG) using a central randomization method.

A single individual, uninvolved in the study, managed the process to ensure allocation concealment. An independent statistician generated a randomization table using the R package “blockrand” (version 4.1.3). The block size and seed number were blinded before being provided to the randomization manager. To maintain balance between the groups, a blocked randomization method was chosen, considering the small sample size. Equal block sizes were used across all sites to ensure consistency in the allocation process.

***INTERVENTION PROTOCOL***

The intervention, Home-Based Pulmonary Rehabilitation Program with Telerehabilitation Support (HBPR-TS), combines traditional pulmonary rehabilitation with digital health support to enhance adherence and outcomes. Designed for post-lung surgery patients, it addresses challenges in maintaining home rehabilitation. Given the high risk of postoperative pulmonary complications, it aims to improve respiratory function, enhance exercise capacity, and support adherence to prescribed rehabilitation through structured home exercises and remote monitoring. By combining in-person education with telemonitoring via instant messaging, the program may provide real-time feedback and individualized support, fostering better long-term outcomes.

***Preoperative and immediate postoperative respiratory training***

Breathing exercises and respiratory muscle training (RMT) were performed before and immediately after surgery using an incentive spirometer (SPIRO-BALL®; Leventon) and a threshold respiratory muscle trainer (IMT/PEP; GH INNOTEK). Participants initiated RMT at 30% of maximal inspiratory pressure (MIP), gradually increasing to 50% as pain subsided. Each session included 10 repetitions per set, with a total of 10 sets performed daily. This preoperative intervention aimed to enhance respiratory function and reduce the risk of postoperative pulmonary complications.

***Postoperative home-based PR program***

At 4 wk post-surgery (baseline), both groups attended a one-time educational session on standardized home-based PR, conducted by a respiratory physiotherapist at the rehabilitation center. The program was delivered through an educational booklet (Appendix file), which provided detailed information on the rationale, procedures, and precautions for each exercise. Furthermore, QR codes linking to instructional photographs and videos were included. The PR program comprised flexibility exercises, aerobic exercises, resistance training, and continued RMT.

Flexibility exercises targeted limb and trunk mobility, performed three times per week. Stretching intensity was self-paced, held for 10 to 15 sec per stretch, and repeated three times per session. Participants performed neck and arm stretches while seated and leg stretches while standing. For aerobic exercise, a recumbent cycle ergometer (706R; Egojin), installed at each participant's home, was used. Sessions occurred three times per week for 40 minutes, including warm-up and cool-down phases. Intensity was based on cardiopulmonary exercise testing (CPX), starting at 40% of heart rate reserve (HRR) and progressing to 70% of HRR, monitored using a fitness tracker (Galaxy Fit2; Samsung). Resistance training consisted of upper and lower limb strengthening exercises using adjustable elastic bands (TheraBandTM; Akron). Participants performed resistance exercises three times per week, with three sets of 15 repetitions per exercise. Respiratory muscle training continued postoperatively using an IMT/PEP device. Participants started at 30% of MIP, increasing to 50% as pain decreased. Each session included 10 repetitions per set, with 10 sets daily.

***Postoperative telerehabilitation (PTR) program IG only***

The IG group received PTR support via a mobile instant messaging application (KakaoTalk; Kakao) three times per week for 4 wk. The PTR program monitored adherence, provided feedback, and adjusted exercise intensity as needed. When retraining or exercise intensity adjustment was needed, education was delivered via text messages, photos, or videos through

a mobile messenger. For participants unfamiliar with the designated mobile messenger, the app was installed and training was provided, considering digital literacy challenges often observed in older adults. However, if participants still had difficulty using the messenger despite training, phone calls were used instead. Two respiratory physiotherapists provided remote supervision through weekly structured messages. The specific instructions and questions provided via messenger included the following:

1) Have you achieved your prescribed exercise goals over the past 2 days?

2) Was the target heart rate on the fitness tracker maintained well during aerobic exercise?

3) Were there any difficulties while performing each exercise?

4) Did you write a self-exercise diary after completing the exercise?

5) Do you have any further questions?

***CG intervention***

Participants in the CG received a second educational session at 8 wk post-surgery at the rehabilitation center. Apart from these two educational sessions, no further communication was provided. Both groups were instructed to maintain their prescribed exercise routines at least three times per week during the 4-wk follow-up period.

***OUTCOME MEASURES***

Outcomes were assessed at four time points in the two rehabilitation centers: preoperatively and at 4 (baseline), 8 (post-intervention), and 12 wk (follow-up) postoperatively. Primary outcomes included VO2peak and predicted VO2peak %, calculated using Hansen's formula based on CPX performed on a treadmill using a cardiac stress system (Q-Stress; Mortara) with a treadmill (TM-55; Mortara). Gas exchange analysis was performed using a metabolic cart (Quark CPET; Cosmed). Secondary outcomes included ventilatory efficiency (VE/VCO2 slope), forced vital capacity (FVC), forced expiratory volume in 1 sec (FEV1), peak expiratory flow (PEF), MIP, grip strength, skeletal muscle index (SMI), body mass index

(BMI), and whole-body phase angle. SMI and whole-body phase angle were measured using a bioelectrical impedance analysis device (S10; InBody) with electrodes attached to the wrist and ankle after 3 minutes of supine rest. The SMI was calculated by dividing skeletal muscle mass (kg) by height squared ($m^2$). FVC, FEV1, PEF, and MIP were assessed using a desktop spirometer (Pony FX; Cosmed) following standardized procedures. Grip strength was measured using a handheld dynamometer (Jamar Plus+, Sammons Preston). Psychological well-being and quality of life were assessed using the Hospital Anxiety and Depression Scale (HADS) and the EuroQol 5-dimension questionnaire (EQ-5D-5L). Adherence to the home-based PR program was recorded in a diary. Daily step counts were recorded using a fitness tracker and extracted from the Samsung Health app on each participant's personal mobile phone. To minimize measurement errors, the average step count was calculated for each week, excluding days with the highest and lowest step counts.

### *STATISTICAL ANALYSIS*

An independent t-test or Wilcoxon rank-sum test was used to compare groups at each time point. Categorical variables were compared using the Chi-square test or Fisher's exact test. Within-group comparisons were performed using paired t-tests. To appropriately account for repeated measurements and missing data, a Linear Mixed Model (LMM) was employed for the primary outcomes (VO2peak and VO2peak%), allowing for unbiased parameter estimation under the Missing At Random (MAR) assumption. Missing data were handled using maximum likelihood (ML) estimation within the LMM framework. Statistical analyses were conducted using R (version 4.2.1; R Core Team). A two-tailed $P \leq .05$ was considered significant.