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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Telerehabilitation for thoracic surgery patients: An effective alternative during the pandemic

Göğüs cerrahisi hastalarında telerehabilitasyon: Pandemi döneminde etkili bir alternatif

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ABSTRACT

Background: This study aims to evaluate the effectiveness of application of physiotherapy via remote telerehabilitation in the early postoperative period following thoracic surgery.

Methods: Between October 2020 and July 2024, a total of 40 patients (25 males, 15 females; mean age: 57.8±9.6 years; range, 42 to 77 years) who underwent thoracic surgery due to Stage 1A-3B non-small cell lung cancer were included in this randomized-controlled clinical study. The patients were divided into two groups: the telerehabilitation group (TG, n=20) and the control group (CG, n=20). Patients in the TG participated in a teleconference-based exercise program supervised by a physiotherapist, starting the day before surgery and continuing daily until discharge. Patients in the CG received a single preoperative exercise session and an educational brochure. All patients were assessed at five time points: preoperatively, immediately after surgery, prior to discharge, at one to three months post-discharge, and at six months post-discharge. Outcome measures included the duration of intensive care unit stay, total hospital stay, chest drain duration, postoperative complications, inflammatory biomarkers, pain, dyspnea, fatigue, spirometry, and State-Trait Anxiety Inventory (STAI) scores.

Results: Both groups had similar baseline characteristics including comorbidities and types of surgery (p>0.05). There were no significant differences in the intensive care unit stay duration (p=0.739), total hospital stay (p=0.311), or chest drain duration (p=0.431) between the groups. However, TG showed significantly lower pain and fatigue levels compared to CG (p<0.05).

Conclusion: Telerehabilitation effectively reduced pain and fatigue in patients after thoracic surgery. The lack of significant differences in other outcomes may be attributed to variations in patient compliance. These findings suggest that telerehabilitation can be a valuable alternative to traditional rehabilitation, particularly during pandemic or isolation.

Keywords: Anxiety, complication, dyspnea, pain, pulmonary rehabilitation, telerehabilitation.

ÖZ

Amaç: Bu çalışmada, göğüs cerrahisi sonrasında erken ameliyat sonrası dönemde uzaktan telerehabilitasyon yoluyla fizyoterapi uygulamasının etkinliği değerlendirildi.

Çalışma planı: Ekim 2020 - Temmuz 2024 tarihleri arasında Evre 1A-3B küçük hücreli dışı akciğer kanseri nedeniyle göğüs cerrahisi yapılan toplam 40 hasta (25 erkek, 15 kadın; ort. yaş: 57.8±9.6 yıl; dağılım, 42-77 yıl) bu randomize kontrollü klinik çalışmaya dahil edildi. Hastalar iki gruba ayrıldı: telerehabilitasyon grubu (TG, n=20) ve kontrol grubu (KG, n=20). TG hastaları, ameliyattan bir gün önce başlayıp taburculuğa kadar her gün fizyoterapist gözetiminde telekonferans temelli bir egzersiz programına katıldı. Kontrol grubundaki hastalara ise yalnızca bir defalık ameliyat öncesi egzersiz seansı ve eğitim broşürü verildi. Tüm hastalar beş zaman noktasında değerlendirildi: ameliyat öncesi, ameliyattan hemen sonra, taburculuktan önce, taburculuktan bir ila üç ay sonra ve taburculuktan altı ay sonra. Sonuç ölçümleri yoğun bakım ünitesinde kalış süresi, toplam hastane yatış süresi, göğüs tüpü kalış süresi, ameliyat sonrası komplikasyonlar, enflamatuvar biyobelirteçler, ağrı, dispne, yorgunluk, Spirometri ve Durumluk-Sürekli Kaygı Envanteri (STAI) skorları idi.

Bulgular: Eşlik eden hastalıklar ve cerrahi türleri dahil olmak üzere her iki grubun başlangıç özellikleri benzerdi (p>0.05). Yoğun bakımda kalış süresi (p=0.739), toplam hastane yatış süresi (p=0.311) ve göğüs tüpü kalış süresi (p=0.431) açısından gruplar arasında anlamlı bir fark bulunmadı. Ancak, TG'nin ağrı ve yorgunluk düzeyleri KG'ye kıyasla anlamlı derecede daha düşüktü (p<0.05).

Sonuç: Telerehabilitasyon, göğüs cerrahisi sonrası hastalarda ağrı ve yorgunluğu etkili bir şekilde azalttı. Diğer sonuçlarda anlamlı farklılıkların olmaması, hasta uyumu ile ilişkili olabilir. Bu bulgular, pandemi veya izolasyon dönemlerinde telerehabilitasyonun geleneksel rehabilitasyona değerli bir alternatif olabileceğini göstermektedir.

Anahtar sözcükler: Anksiyete, komplikasyon, dispne, ağrı, pulmoner rehabilitasyon, telerehabilitasyon.

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Novel coronavirus disease 2019 (COVID-19), caused by the virus severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2), spreads rapidly through droplet and contact transmission, potentially infecting healthcare personnel and leading to irreversible conditions or fatalities.[1] Physiotherapists, due to their close contact with patients, are particularly vulnerable to respiratory droplet exposure. As a result, it is essential to implement standard infection control measures and use high-grade personal protective equipment during physiotherapy and rehabilitation interventions, when clinically necessary.[2-6] However, these precautions can limit access to physiotherapy services, impacting postoperative care in thoracic surgery clinics worldwide.

Physiotherapy effectively prevents pulmonary complications in both preoperative[7] and postoperative[5] periods of thoracic surgery, improves physical functions.[8] Post-surgical issues such as dyspnea, pain, fatigue, and altered lung function significantly affect quality of life,[9] with physiotherapy being a key intervention. However, infection risks associated with techniques like deep breathing exercises[10] during isolation periods highlight the need for safer alternatives. In this context, telerehabilitation has emerged as a solution which ensures continuity of care while minimizing infection risks.[11] It offers a practical solution for patients with limited access to clinics or those requiring long-term rehabilitation,[12] particularly individuals with cardiac,[13] pulmonary,[14] and orthopedic conditions.[10]

Two studies have been published examining telerehabilitation applications in lung cancer cases, both involving patients undergoing chemotherapy and excluding those who underwent surgery.[15,16] To the best of our knowledge, this study is the first to evaluate the effectiveness of postoperative physiotherapy via telerehabilitation, particularly during isolation periods.

In the present study, we aimed to investigate the effectiveness of telerehabilitation-based physiotherapy in the early postoperative period following thoracic surgery and to compare telerehabilitation to self-directed exercises, aiming to highlight its potential application not only during pandemics, but also in future situations requiring patient isolation.

PATIENTS AND METHODS

This single-center, randomized-controlled clinical study was conducted at İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, Department of Thoracic Surgery between October 2020 and July 2024. Patients diagnosed with lung cancer who underwent thoracotomy or video-assisted thoracoscopic surgery (VATS) were randomly assigned to the telerehabilitation group (TG) and control group (CG) using block randomization. Baseline assessments for all patients were conducted the day before the operation, and preoperative physiotherapy education was provided to them on the same day. A written informed consent was obtained from each patient. The study protocol was approved by the Cerrahpaşa Medical Faculty Clinical Research Ethics Committee (date: 04.08.2020, no: 17109671-605-99-94310). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The study included patients with Stage 1A-3B non-small cell lung cancer (NSCLC) and confirmed lung tumors which significantly affected their quality of life, as determined by clinical evaluations and patient-reported symptoms such as dyspnea, fatigue, and pain. Eligible patients were those scheduled for thoracotomy or VATS and who owned a smartphone capable of video calls. The major inclusion criterion was having an American Society of Anesthesiologists (ASA) Class ≥II, indicating the absence of significant cardiac comorbidities which could affect quality of life. Patients were excluded if they had significant cardiac diseases, severe cognitive impairments, psychiatric disorders, physical limitations (e.g., visual or hearing impairments, or orthopedic conditions), or lacked a confirmed diagnosis of lung cancer following frozen-section analysis. Those who underwent wedge resection or did not own a smartphone were also excluded. Patients who did not meet the inclusion criteria, such as those without a smartphone or with disqualifying medical conditions, were excluded from the study and were not included in the flowchart. Of a total of 67 cases evaluated, 40 (25 males, 15 females; mean age: 57.8±9.6 years; range, 42 to 77 years) who met the inclusion criteria were recruited (Figure 1).

Interventions

The TG group consisted of 20 patients who were transferred from the intensive care unit (ICU) to the ward on the first postoperative day and assessed and provided with an exercise program via teleconference. A physiotherapist conducted the sessions using a secure and encrypted data transfer platform on the patient's phone for a duration of 30 min. Due to the COVID-19 pandemic,

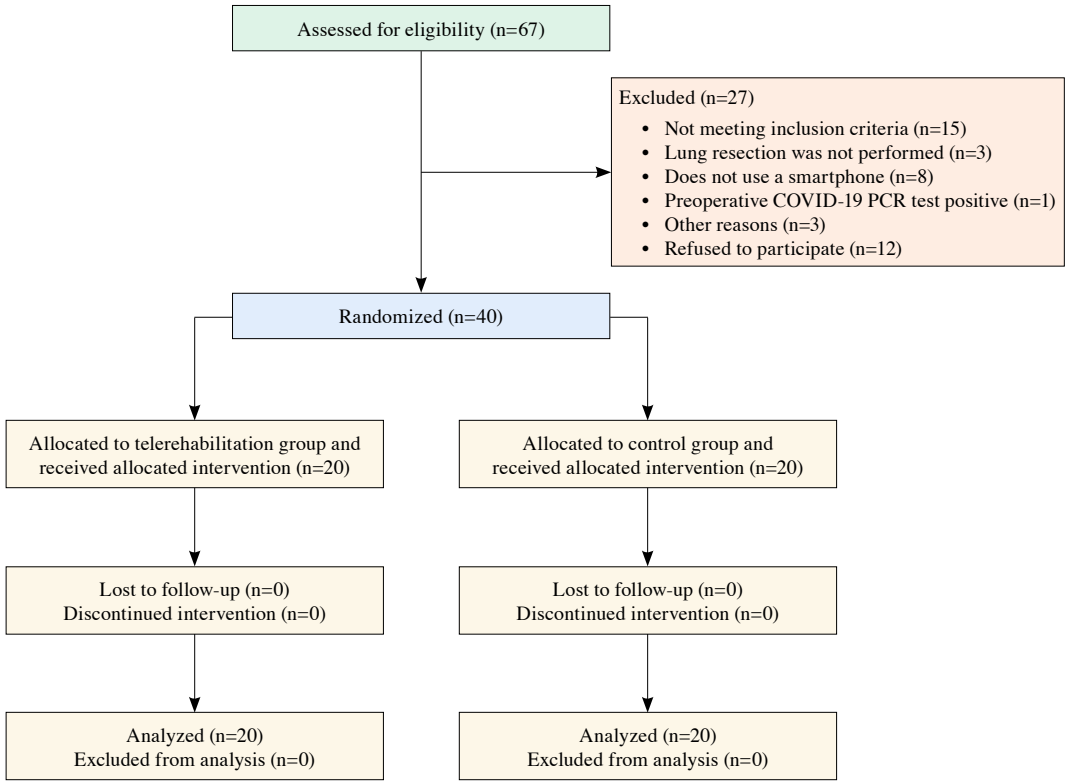

Figure 1. Study flowchart.

no healthcare workers or attendants were present in the patient's room during the exercise sessions. Nurses securely placed the patient's phone on a bedside portable table, which also held an incentive spirometer, a pulse oximeter, and a sheet displaying the Numerical Rating Scale (NRS).

Exercises were performed individually by the patients rather than in groups. Although all patients were required to test negative for SARS-CoV-2 ribonucleic acid (RNA) at least twice before surgery, it could not be guaranteed that they were free of the virus. During the exercises, patients' oxygen saturation and heart rate were monitored using a portable pulse oximeter, and regular feedback was obtained from the patients to ensure safety. Additionally, patients recorded their pain, dyspnea, and fatigue levels using the NRS before and after each session. These scores were documented by the physiotherapist along with feedback obtained from the patients.

The exercise program included respiratory exercises (chest, abdominal, and lateral basal breathing; 10 reps each), incentive spirometer use (10 reps, 2 sets), assisted coughing, and indoor walking. A progressive early mobilization program was also implemented, tailored to the patient's tolerance and hemodynamic parameters upon ward admission. Teleconference sessions were conducted twice daily from the first postoperative day until discharge.

The patients were instructed to independently perform the breathing exercises and use the incentive spirometer every 2 h while awake, in addition to participating in the teleconference sessions. They were also encouraged to walk inside their rooms twice daily for at least 15 min per session.

The CG consisted of 20 patients who were admitted to the ward from the ICU on the first postoperative day and were assessed via teleconference using a phone, and an exercise information brochure was provided. The brochure contained detailed instructions on respiratory exercises, the use of the incentive spirometer, coughing techniques, and the importance of walking. It was ensured that the patient understood the content of the brochure. The patient was instructed to perform the breathing exercises outlined in the brochure and to use the incentive

spirometer independently every 2 h while awake. Additionally, the patient was advised to walk inside the room four times a day for at least 15 min each session.

Study outcomes

Assessments were conducted at five time points: preoperatively, immediately after surgery, prior to discharge, at one to three months post-discharge, and at six months post-discharge. Demographic characteristics, comorbidities, diagnoses, and smoking histories of the patients were documented. Additionally, respiratory function parameters were measured, and peripheral arterial blood samples were analyzed for partial blood gas pressures.

Pulmonary function tests were performed using desktop spirometry (Cosmed/Pony Fx, Italy) in accordance with the standards of the American Thoracic Society (ATS) and the European Respiratory Society (ERS).[17] The parameters included functional vital capacity (FVC), forced expiratory volume in 1 sec (FEV_1), and peak expiratory flow (PEF), and lung capacities were assessed. Furthermore, carbon monoxide diffusion capacity (DLCO) and DLCO divided by the alveolar volume (DLCO/VA) values were analyzed.[15]

To evaluate functional exercise capacity, a 6-Min Walk Test (6MWT) was administered.[18] This test was conducted one-on-one by a physician in the surgical clinic. Dyspnea severity was assessed using the modified Medical Research Council (mMRC) Dyspnea Scale[19] which rates dyspnea on a scale from 0 (no dyspnea) to 4 (severe dyspnea). Patients also scored their levels of dyspnea, pain, and fatigue using a NRS ranging from 0 to 10, with 0 representing no symptoms and 10 indicating very severe symptoms. Scores were recorded both before and after exercise.

Blood tests were performed to determine partial pressure of oxygen (PaO_2), partial pressure of carbon dioxide ($PaCO_2$), and oxygen saturation (SaO_2). In addition, inflammatory biomarkers including C-reactive protein (CRP), procalcitonin,[20] ferritin,[21] D-dimer,[22] and lactate dehydrogenase (LDH)[23] values were recorded.

Psychological status was assessed using the State-Trait Anxiety Inventory (STAI)[24] measures both state anxiety (related to a specific event) and trait anxiety (a general characteristic). The inventory, consisting of 40 questions rated on a four-point Likert scale, generates scores ranging from 20 to 80, with higher scores indicating greater anxiety. Anxiety levels were measured both before and after surgery.

Complication status including fever, infection, and bleeding, drainage days, days spent in the ICU, and length of hospital stay were also recorded.

Statistical analysis

Study power analysis and sample size calculation were performed using the G*Power version 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The minimum number of individuals required to be included in the study was calculated based on the 6MWT distance used in a similar previous study.[25] Using the data from this study, the effect size was determined to be 0.88. Considering an effect size of 0.88, α=0.05, and power=0.95, the minimum number of individuals for the intervention group was calculated to be 20. Assuming an equal number of individuals for the CG, the sample size was calculated as 40.

Statistical analysis was performed using the IBM SPSS version 26.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The normality of quantitative variables was assessed using the Shapiro-Wilk test. Since the assumptions for parametric tests were not met, the Mann-Whitney U test was used for comparisons between independent groups, and the Wilcoxon signed-rank test was used for comparisons between dependent groups. The Friedman test was also employed to compare more than two dependent groups. A two-tailed p value of <0.05 was considered statistically significant.

RESULTS

There was no significant difference in the baseline characteristics, including demographic data, comorbidities, exercise capacity, respiratory function, and arterial blood gas levels between the groups (Table 1).

Comparing the types of surgical resections, lobectomy was the most frequently performed procedure in the TG, whereas both lobectomy and wedge resection were common in the CG (p=0.207). There were no statistically significant differences between the groups regarding surgical resection types, ICU stay duration, total hospital stay, or chest tube duration (Table 1).

However, complication rates were significantly lower in the TG compared to the CG (p=0.02),

Table 1. Demographic and baseline clinical features of the groups

	Telerehabilitation group					Control group					
	n	%	Mean±SD	Median	Min-Max	n	%	Mean±SD	Median	Min-Max	*p*
Age (year)			58.2±11.1					57.5±8.1			0.776
Sex											0.333
Male	10	50				15	90				
Female	10	50				5	30				
BMI (kg/m^2)			26.47±4.01					27.28±5.45			0.978
Smoking statues (pack x year)			49.90±41.33					33.40±21.71			0.207
Comorbidities											
HT	5	26.3				8	38.1				0.500
DM	3	15.8				6	28.6				0.225
Diagnosis											
Carcinoma	20	100				20	100				<0.001
Exercise capacity											
6MWD (m)			369.50±70.07					344.15±80.62			0.337
mMRC (0-4)**				1	0-2				1	0-2	0.050
Pulmonary functions											
FVC (L)			3.14±0.57					3.48±0.44			0.080
FVC (%)			92.19±10.60					98.29±13.44			0.065
FEV_1 (L)			2.48±0.45					2.80±0.44			0.072
FEV_1 (%)			84.06±10.71					94.39±16.94			0.093
FEV_1/FVC			78.72±14.15					79.63±9.16			0.745
PEF (L)			6.18±1.09					6.87±1.16			0.105
PEF (%)			85.68±10.54					95.24±17.56			0.057
Diffusion capacity											
DLCO measured (mmol/kPa.sec)			16.52±7.79					20.61±6.65			0.078
DLCO % predicted			79.28±14.77					86.36±15.37			0.057
DLCO/VA (DLCO/L)			3.82±1.41					4.36±1.20			0.293
DLCO/VA % predicted			91.84±26.07					98.20±20.85			0.100
Lung capacities											
TLC measured			5.13±0.94					5.54±0.44			0.081
TLC % predicted			85.53±8.15					90.14±6.35			0.139
RV measured			2.22±0.50					2.55±1.02			0.081
RV % predicted			98.05±15.64					99.62±14.03			0.278
RV/TLC			63.92±19.09					64.81±27.80			0.768
Inflamatuar biomarkers											
CRP			11.23±18.84					17.39±24.66			0.646
Ferritin			89.36±55.43					125.74±111.36			0.507
Precalcitonin			0.06±0.05					0.08±0.117			0.636
DDMER			1.59±1.73					1.76±2.80			0.543
LDH			230.10±77.44					226.40±53.10			0.903
Blood gases											
PaO_2 (mmHg)			88.58±16.44					80.40±13.26			0.096
$PaCO_2$ (mmHg)			36.43±5.12					37.88±4.37			0.245
SaO_2			96.97±1.47					94.52±6.03			0.053
Operation type											0.207
Lobectomy			13	65				9	45		
Bilobectomy			1	5				0	0		
Pneumonectomy			0	0				2	10		
Wedge			6	30				9	45		
Complication											**0.002**
Empyema	0	0						1	5		
Pneumonia	0	0						1	5		
Scalenus lap	0	0						1	5		
Atelectasis	0	0						1	5		
Prolonged air leak	2	10						0	0		
Bronchopleural fistula	0	0						1	5		
Elevated creatinine (chronic renal failure)	0	0						1	5		
Pneumoderma	1	5						0	0		
Sinus tachycardia	0	0						1	5		
ICU stay time (day)			0.35±0.48							0.30±0.47	0.739
Drain stay time (day)			4.95±4.78							3.35±1.66	0.431
Hospital stay time (day)			6.60±5.10							5.00±2.49	0.311

SD: Standard deviation; BMI: Body mass index; HT: Hypertansion; DM: Diabetes mellistus; 6MWT: Six-minute walk distance; mMRC: Modified Medical Research Council Dyspnea Scale; FVC: Forced vital capacity; FEV_1: Forced Expiratory volume in 1 second; PEF: Peak expiratory flow; DLCO: Diffusing capacity of the lungs for carbon monoxide; VA: Alveolar ventilation; TLC: Total lung capacity; RV: Residual volume; CRP: C-reactive protein; DDMER: Directly determined maximum expiratory rate; LDH: Lactate dehydrogenase; PaO_2: Partial pressure of oxygen in arterial blood; $PaCO_2$: Partial pressure of carbon dioxide in arterial blood; SaO_2: Arterial oxygen saturation; ICU: Intensive care unit.

Table 2. Changes in pulmonary function test results of the groups

	Telerehabilitation group						Control group						Difference between groups		
	Preoperative	POM 1st-3th	POM 6th				Preoperative	POM 1st-3th	POM 6th				Preoperative	POM 1st-3th	POM 6th
	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c			
Pulmonary functions															
FVC (L)	3.14±0.57	2.84±0.73	2.11±0.54	**0.044**	**<0.001**	**<0.001**	3.48±0.44	3.16±0.71	2.12±0.35	**0.032**	**<0.001**	**<0.001**	0.080	0.129	0.665
FVC (%)	92.19±10.60	82.12±15.10	74.18±13.37	**0.014**	**0.002**	**0.002**	98.29±13.44	89.21±19.79	75.02±11.33	**0.021**	**<0.001**	**<0.001**	0.065	0.107	0.507
FEV_1 (L)	2.48±0.45	2.18±0.66	2.78±0.66	**0.046**	**0.025**	**0.001**	2.80±0.44	2.19±0.46	3.16±0.65	**<0.001**	**0.038**	**<0.001**	0.072	0.882	**0.025**
FEV_1 (%)	84.06±10.71	75.73±18.37	78.53±12.87	**0.024**	0.167	0.607	94.39±16.94	80.46±21.46	85.29±15.48	**0.004**	0.277	**0.006**	0.093	0.343	0.133
FEV_1/FVC	78.72±13.39	86.92±17.56	86.91±13.93	**0.040**	**0.028**	0.060	79.63±8.67	77.94±16.08	77.83±16.44	0.777	0.433	0.428	0.745	0.058	0.045
PEF (L)	6.18±1.09	4.68±1.42	5.18±0.81	**0.002**	**0.003**	**<0.001**	6.87±1.16	5.58±1.48	5.62±1.33	**0.008**	**0.005**	0.004	0.105	**0.032**	0.039
PEF (%)	85.68±10.54	67.15±13.09	115.85±24.57	**0.001**	**0.001**	**<0.001**	95.24±17.56	65.11±10.01	119.79±36.46	**<0.001**	**0.002**	**<0.001**	0.057	0.435	0.892

POM: Postoperative month; SD: Standard deviation; a: Preoperative and postoperative 1-3th month comparison; b: Preoperative and postoperative 6th month comparison; c: Friedmann; FEV_1: Forced expiratory volume in 1 second; FEV_1/FVC: Forced expiratory volume in 1 second to forced vital capacity ratio; FVC : Forced vital capacity; PEF: Peak expiratory flow.

Table 3. Changes in inflammatory biomarkers of the groups

	Telerehabilitation group								Control group								Difference between groups		
	Preoperative	Discharge	POM 1st-3rd	POM 6th					Preoperative	Discharge	POM 1st-3rd	POM 6th					Discharge	POM 1st-3rd	POM 6th
Inflamatuar biomarkers	Mean±SD	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c	p^d	Mean±SD	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c	p^d			
CRP	11.23±18.84	84.01±81.64	26.63±54.12	26.14±41.81	**<0.001**	0.681	0.156	**<0.001**	17.39±24.66	84.10±74.81	14.13±14.38	11.44±12.04	**<0.001**	0.970	0.502	**<0.001**	0.882	0.417	0.565
Ferritin	89.36±55.43	131.87±104.33	141.55±167.69	168.41±274.22	**0.002**	0.153	0.117	0.068	125.74±111.36	207.24±157.02	152.71±197.84	131.49±110.01	**<0.001**	0.737	0.546	**0.009**	0.137	0.968	0.879
Procalcitonin	0.06±0.05	0.29±.38	0.13±0.25	0.22±0.28	**0.004**	0.444	**0.020**	**0.007**	0.08±0.11	3.15±12.68	0.14±0.19	0.31±0.87	**0.001**	0.133	0.296	**0.001**	0.903	0.498	0.620
DDMER	1.59±1.73	1.82±1.56	1.65±2.11	1.12±1.29	0.469	0.629	0.737	0.491	1.76±2.80	1.79±1.04	1.63±1.55	1.07±0.86	0.232	0.970	0.526	0.198	0.636	0.715	0.602
LDH	230.10±77.47	219.65±66.74	195.15±35.93	201.51±52.13	0.324	0.083	0.135	**0.041**	226.40±53.102	209.50±54.49	227.45±110.61	218.05±80.38	0.198	0.411	0.351	0.424	0.441	0.304	0.659

POM: Postoperative month; SD: Standard deviation; a: Preoperative discharge comparison; b: Preoperative and postoperative 1st-3rd month comparison; c: Preoperative and 6th month comparison; d. Friedmann; CRP: C-reactive protein; DDMER: Directly determined maximum expiratory rate; LDH: Lactate dehydrogenase.

suggesting that early physiotherapy interventions in the TG contributed to a reduction in both the severity and frequency of postoperative complications. In the TG, complications included prolonged air leaks and pneumoderma, while complications in the CG included emphysema, pneumonia, scalene lap, atelectasis, bronchopleural fistula, elevated creatinine levels, and sinus tachycardia (Table 1).

In terms of pulmonary function, both groups demonstrated an overall decline in test results. Nonetheless, the TG exhibited a statistically significant improvement in PEF compared to the CG (p=0.032), indicating that early mobilization and physiotherapy likely reduced some of the expected respiratory decline. No other pulmonary function parameters differed significantly between the groups (p>0.05) (Table 2).

Although inflammatory markers such as CRP and procalcitonin did not differ significantly between the groups (Table 3), the TG showed a trend toward fewer complications and a smoother recovery, which was thought to be related to early physiotherapy interventions (Table 3).

The mMRC dyspnea scores revealed significant intra-group increases in both groups while comparing preoperative values to those on postoperative Day 1 (p=0.049) and at discharge (p=0.049). Pain levels, measured using the NRS, increased more in the CG than in the TG from preoperative to postoperative Day 1 (p=0.027). Similarly, fatigue scores, also assessed using the NRS, were higher in the CG than in the TG (p=0.011). These results suggest that early physiotherapy support in the TG contributed to a more stable recovery with reduced pain and fatigue levels postoperatively.

Anxiety inventory scores showed no significant changes either within or between the groups (p>0.05) (Table 4).

DISCUSSION

In the present study, we explored the impact of telerehabilitation-based physiotherapy during the early postoperative period following thoracic surgery, comparing it to a CG that performed self-directed exercises without structured intervention. The study group participated in twice-daily telerehabilitation sessions, while the CG followed no structured program, reflecting the real-world challenges of the COVID-19 pandemic, which limited access to in-person physiotherapy. The TG demonstrated significant improvements, including reduced

Table 4. Comparison of symptomatic conditions and anxiety levels of the groups

	Telerehabilitation group							Control group							Difference between groups		
	Preoperative	POD 1st	Discharge	POM 1st-3th				Preoperative	POD 1st	Discharge	POM 1st-3th						
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c	p^d	Mean±SD	Mean±SD	Mean±SD	Mean±SD	p^a	p^b	p^c	p^d	p^a	p^b	p^c
mMRC (0-4)**	1 (0-2)	1 (0-2)	1(0-2)	1(0-3)	**0.025**	**0.025**	1.000	**0.040**	1 (0-2)	1 (0-2)	1(0-2)	0(0-2)	**0.034**	**0.034**	**0.001**	**<0.001**	**0.049**	**0.049**	0.466
NRS																			
Pain	0.60±1.50	3.80±2.21	3.30±2.40	0.65±1.63	**<0.001**	**0.001**	0.854	**<0.001**	0.85±1.78	5.20±1.88	4.45±1.31	0.45±0.88	**<0.001**	**<0.001**	0.552	**<0.001**	**0.027**	**0.048**	0.615
Dyspnea	1.65±2.20	2.25±2.31	2.15±2.20	1.60±1.95	0.103	0.090	0.959	0.374	3.10±2.71	3.90±2.53	3.50±2.13	1.05±1.27	0.298	0.572	**0.004**	**<0.001**	0.077	0.057	0.539
Fatigue	2.70±2.88	2.70±2.99	2.35±2.68	1.10±1.44	0.751	0.376	**0.008**	**0.001**	3.45±2.74	4.90±2.57	4.00±2.10	1.20±1.32	0.116	0.605	**0.003**	**<0.001**	**0.011**	**0.029**	0.670
STAI																			
Situationality	42.50±5.13	40.80±5.29	41.75±5.42	45.45±4.26	0.093	0.757	0.005	<0.001	44.65±5.82	43.75±6.76	43.65±6.59	45.15±4.83	0.355	0.135	0.717	0.335	0.146	0.363	0.913
Continuity	46.55±4.65	45.90±4.54	46.15±4.30	45.75±4.58	0.408	0.916	0.754	0.925	45.95±4.00	45.65±4.28	46.10±3.40	45.30±3.01	0.452	1.000	0.793	0.697	0.605	0.859	0.754

POD: Postoperative day; POM: Postoperative month; SD: Standard deviation; a: Preoperative postoperative 1st day; b: Preoperative discharge comparison; c: Preoperative and postoperative 1st-3th month comparison; d: Friedmann; mMRC: Modified Medical Research Council Dyspnea Scale; NRS: Numeric rating scale; STAI: State-Trait Anxiety Inventory Scores.

dyspnea and fatigue, as well as fewer complications. These findings underscore the importance of early and continuous physiotherapy interventions via telerehabilitation in enhancing postoperative outcomes.

Chest physiotherapy has a positive impact on postoperative patient outcomes. It is recommended to initiate physiotherapy in the preoperative period and continue it throughout the postoperative hospital stay and recovery phases.[26] In our study, early telerehabilitation effectively reduced postoperative complications by enhancing lung hygiene and promoting early mobilization. This highlights the essential role of continuous physiotherapy in managing complications after lung surgery.

Telerehabilitation ensures continuity of care during isolation or for patients who are unable to access hospitals.[27] It can be delivered synchronously or asynchronously, utilizing web-based, videoconference, or video-based formats.[28] While widely used for various groups, its application in early postoperative lung surgery patients has not been previously studied.[29,30] Our pioneering study demonstrates telerehabilitation's potential as a valuable tool for managing postoperative recovery, emphasizing its clinical importance.

A retrospective study found that physiotherapy after lobectomy reduced pulmonary complications, hospital stays, medication use, and healthcare costs.[31] Similarly, a systematic review reported no significant effects of interventions such as aerobic training on mortality, complications, or lung function.[32] In contrast, our study focused on lung volumes, hygiene, and ambulation, demonstrating that early physiotherapy significantly reduced complications. Despite similar ICU stay, drainage time, and hospital stay, the study group had fewer complications, highlighting the benefits of early physiotherapy and validating teleconference-based delivery.

Inflammatory markers typically increase following major thoracic surgery, with CRP remaining elevated for up to a month.[33] Postoperative CRP levels may also have prognostic value in non-small cell lung cancer, while elevated LDH levels are linked to increased morbidity.[34] To the best of our knowledge, no studies have examined the effect of physiotherapy on CRP and LDH following lung resection in the literature yet. Our study is the first to investigate these biomarkers in the context of early postoperative telerehabilitation, providing novel insights into its physiological benefits.

In addition to the physical aspects of pain, anxiety plays a significant role in modulating postoperative pain experiences. Studies have shown that patients with higher preoperative anxiety levels tend to report increased postoperative pain.[35,36] Moreover, telemedicine interventions have been effective in reducing anxiety levels, as they provide patients with accessible mental health services from the comfort of their homes, thereby minimizing stressors associated with in-person visits.[37] In our study, the implementation of telerehabilitation not only facilitated physical recovery, but also offered psychological support, potentially alleviating anxiety related to postoperative recovery. This dual benefit underscores the value of integrating telerehabilitation into postoperative care plans to address both physical and emotional aspects of patient health.

Nonetheless, our study has several limitations. First, the inclusion of different surgical procedures, such as anatomical lung resections and sublobar resections, may have contributed to variations in outcomes, particularly regarding the amount of lung tissue removed, which could influence postoperative recovery. Second, the evaluations were limited to a short postoperative window, which may have affected the long-term assessment of certain biomarkers. This constraint also led to gaps in blood gas measurements, which could not be included in the data presentation. Third, although the sample size was determined based on a power analysis and was adequate for the study, a larger sample size could have enhanced the generalizability and robustness of the findings considering the dropout rates. Furthermore, the one-year follow-up, while sufficient to capture short-term postoperative outcomes, limited the study's ability to evaluate long-term recovery. A longer follow-up could provide more comprehensive insights into extended recovery and outcomes.

In conclusion, this study is the first to examine the effectiveness of in-hospital telerehabilitation for delivering physiotherapy in the early period after lung resection. Additionally, it is the first study to assess the impact of physiotherapy on biomarkers such as C-reactive protein and lactate dehydrogenase. These findings suggest that early physiotherapy delivered via telerehabilitation is associated with lower complication rates, less pain, and reduced fatigue, highlighting the potential benefits of this approach in enhancing postoperative recovery. Based on these findings,

telerehabilitation-based physiotherapy seems to be an applicable and effective method. However, further multi-center, large-scale, randomized-controlled clinical studies are warranted to establish more reliable conclusions on this subject.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, literature review, writing the article: E.P.; Design: E.P., A.T.; Control/supervision: E.P., B.K., A.T.; Data collection: A.E.A., S.G.A., Y.G.; Statistical analysis: A.E.A.; Critical review: A.T., B.K. All authors approved the final version of the manuscript.

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