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Original Article

The Effect of Early Rehabilitation and Diaphragmatic Kinesio Taping on Diaphragm Muscle Thickness in Patients with Severe COVID-19 Pneumonia in the Intensive Care Unit

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ABSTRACT

Background The efficacy of early rehabilitation in patients in the intensive care unit is apparent. However, it is still unclear in COVID-19 patients. Also, the effects of diaphragm kinesiotaping on outcomes and muscle thickness were not shown previously. Thus, we aimed to investigate the efficacy of rehabilitation and diaphragm kinesiotaping in patients with severe COVID-19 pneumonia by evaluating with the ultrasonography of the diaphragm.

Methods Patients with severe COVID-19 pneumonia in intensive care unit requiring high flow oxygen therapy included in the study. Patients with severe COVID-19 pneumonia in intensive care unit requiring high flow oxygen therapy were divided into three groups: Group 1 (n = 22) rehabilitation, group 2 (n = 26) rehabilitation and diaphragm kinesiotaping, Group 3 (n = 24) control group-only standard intensive care unit care. Ultrasonographic measurements of diaphragm thickness and thickening fraction were recorded repeatedly.

Results The demographic characteristics, mortality, and length of stay were not different between groups. However, invasive mechanic ventilation requirement and the decrease in diaphragm thickness and thickening fraction values were significantly lower in the diaphragm kinesiotaping group. Baseline diaphragm thickness and thickening fraction values were found to impact invasive mechanic ventilation requirement. Cut-off values for these parameters are 2.85 mm and 37.95%, respectively.

Conclusion Baseline diaphragm thickness can be used to predict noninvasive ventilation failure. By the way, the patients who are more likely to develop respiratory failure should receive inspiratory muscle training exercises combined with general rehabilitation principles. Also, diaphragm kinesiotaping should be included in the rehabilitation protocol.

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INTRODUCTION

Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was declared a pandemic by the World Health Organization on March 11, 2020.[1] COVID-19 has a large spectrum. While respiratory symptoms are commonly associated with COVID-19, the disease can affect multiple organ systems and present with various symptoms, including anorexia, nausea and diarrhoea, myocarditis, skeletal muscle myopathy, and generalized debility.[2] These patients are at risk of substantial deconditioning as they are confined to bed from systemic symptoms and profound hypoxemia.

Patients with COVID-19 admitted to the intensive care unit (ICU) are at high risk of developing ICU-acquired weakness. This condition refers to muscle weakness resulting from prolonged immobility and critical illness during an ICU stay. ICU-acquired weakness has been associated with various negative outcomes, including an increased length of stay in the ICU, difficulty in weaning from mechanical ventilation (the process of removing a patient from a ventilator), impaired mobility performance, reduced exercise tolerance, decreased independence with activities of daily living upon discharge, and lower overall quality of life for the patient.[3,4] Given the complex nature of COVID-19 and the potential complications that can arise, the management of COVID-19 in the ICU necessitates a multidisciplinary approach.[4]

Rehabilitation programs in the early stages of acute respiratory distress syndrome in ICU patients are known to be beneficial.5 The advantages of early rehabilitation strategies are; reducing complications of immobilization, improving either musculoskeletal or respiratory functions, and accelerating recovery time with minimal impairment.5 However, there is limited data about the efficacy and safety of the early rehabilitative approach in the ICU for COVID-19 patients.[6-8]

The diaphragm is the primary respiratory muscle, and the diaphragm weakness that precipitates respiratory failure develops in critically ill patients.[9] Respiratory muscle performance screening for management in COVID-19 patients has been recommended recently.[10,11] Ultrasound (US) is readily available, applicable, non-invasive, and provides direct visualization of diaphragmatic motion.[9] Several studies have shown the accuracy and reproducibility of US for evaluating diaphragm function. The parameters evaluated by the US for diaphragm dysfunction and atrophy are diaphragm thickness, thickening fraction, and diaphragm mobility.[9,10]

Kinesio taping, which Dr Kenso Kase first developed, is primarily used in musculoskeletal system disorders.[12] Kinesio tape is a latex-free, thin and elastic adhesive material. Increasing blood and lymphatic circulation, decreasing inflammation, stimulating mechanoreceptors, and producing proprioceptive input is the mechanism for the Kinesio tape effects. The effects on muscle strength depend on the application technique; muscle activity can be facilitated or inhibited.[12,13] Kinesio taping was also suggested as beneficial for respiratory functions in healthy controls[14] and ventilatory-induced diaphragm dysfunction.[15] We aimed to investigate the efficacy of rehabilitation and Kinesio taping of the diaphragm in patients with severe COVID-19 pneumonia by evaluating with ultrasonography of the diaphragm.

MATERIAL AND METHODS

Patients with severe COVID-19 pneumonia requiring high-flow oxygen therapy in the adult ICU of our hospital were enrolled in this prospective, randomized, controlled study. The Hospital's Medical Ethics Committee approved this study (The decision number is 2020-3/12.). The principles of the Declaration of Helsinki conducted the study.

Participants and study groups

Severe COVID-19 pneumonia was diagnosed clinically by an anesthesiologist and confirmed by a reverse transcription-polymerase chain reaction assay of a nasopharyngeal swab specimen and computed tomography of the thorax. After evaluating eligibility, 72 patients in the ICU in August-October 2020 were included in intervention groups. The patients were randomized into two groups by a simple randomization method with random-number tables. In Group 1, a rehabilitation program was applied to patients. And diaphragm Kinesio tape was used additionally to the rehabilitation program in Group 2. Patients hospitalized after May 2020 received regular rehabilitation programs routinely added to standard care in ICU. The control group (historical) included patients admitted to ICU before May 2020 (Group 3, n: 24) and received only standard ICU care. Patients in the control group were selected based on the same inclusion and exclusion criteria. All the participants in the intervention groups gave written informed consent. The interventions and evaluation were interrupted if the patient was intubated or died.

The exclusion criteria included the following: mental impairment, altered level of consciousness, Glasgow Coma Scale < 15; heart rate less than 50/min or > 120/min; blood pressure less than 90/60 mmHg or > 180/90 mmHg; new onset of arrhythmia and myocardial ischemia; skin lesions on the body and presence of skin hypersensitivity reaction history; patients who underwent mechanical ventilation; patients who were under sedatives and neuromuscular blocking agents; age under 18; pregnancy; receiving treatment except for standard ICU care.

Standard management in ICU

All patients have received standard ICU care. Patients were monitored for electrocardiogram, blood pressure, and oxygen saturation. Medical treatment consisted of hydroxychloroquine, favipiravir, antibiotic therapy, anticoagulation, and methylprednisolone (1 mg/kg). Hydroxychloroquine with a loading dose of 400 mg twice daily followed by 200 mg per day twice daily for additional five days, favipiravir with a loading dose of 1,600 mg twice daily followed by 600 mg per day twice daily for other five days and azithromycin with a loading dose of 500 mg daily followed by 250 mg per day for additional five days, unless contraindicated. If needed, nutritional support and intravenous hydration were administered. Patients were discharged from ICU if they were clinically stable and oxygen saturation was > 93% (without oxygen or with 2-3 L/min nasal oxygen support).

Rehabilitation protocol

Patients received rehabilitation as soon as they were hemodynamically stable after being evaluated by a physical medicine and rehabilitation (PMR) specialist. The same physical therapist conducted the physical therapy program. Due to the rapid transmission of coronavirus by droplet spread and close contact, complete personal protective equipment, including gloves, FFP2 masks, isolation gowns, face shields, and goggles, are provided to protect healthcare professionals. According to the guideline for rehabilitation principles in COVID-19 prepared by the Cardiopulmonary Rehabilitation Study Group of the Turkish Society of PMR Specialists, the rehabilitation program is determined.[11]

An individualized program was prescribed. The protocol consisted of the following: positioning in bed; frequent position changes; passive/active-assisted and active joint range of motion exercises; isometric muscle strengthening; inspiratory muscle training exercises (voluntary isocapnic hyperpnea); bronchial hygiene-airway clearance techniques (controlled cough and huffing, postural drainage, tri-flow); controlled breathing techniques (diaphragmatic breathing, pursed-lip breathing, glossopharyngeal breathing).

The same Physical therapist administered physical therapy daily for approximately 30-40 minutes and five days a week. Heart rate, respiratory rate, mean blood pressure and oxygen saturation were monitored during the protocol. The program was stopped if there was a deterioration of these parameters.

Applying kinesio tape

Kinesio tape was applied to the diaphragm from

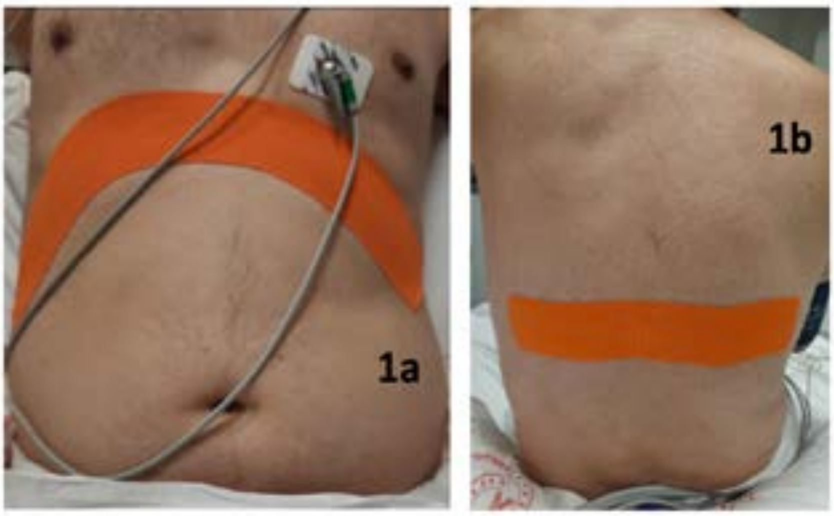

Figure 1. Kinesiotaping of diaphragm muscle. 1a: taping diaphragm from abdomen (anterior); 1b: taping diaphragm from back (posterior).

the back (posterior) and abdomen (anterior) with a Kinesio Tex Tape (Kinesio University, Albuquerque, USA). Tape placement sites were determined according to techniques described by Kase *et al.*[12] Muscle facilitation technique was applied to the diaphragm muscle from proximal to distal with 10-15% tension. The taping on the diaphragm from the abdomen (anterior) was performed during expiration. The base point of an "I" shaped Kinesio tape was applied 1 inch (2.5 cm) below the xiphoid process. After maximum deep inspiration, when the rib cage is maximally expanded, the tails of the tape were applied with 10% tension on the rib cage. Then, a second "I" shaped Kinesio tape was used from the back. The base point was used on the 12th thoracic vertebra with 50-75% tension, and the tails were applied towards the ribs without any tension (Figure 1). At that time, the patient held their breath after maximum deep inspiration. The same physician used Kinesio tape at a 3-4 day interval.

Data collection and outcome measures

Demographic data, hospital-ICU stay duration, mortality, and mechanical ventilation requirement were recorded. Diaphragm measurements were prospectively recorded on admission (day 0), on day 3, on day six, and on day 9.

Ultrasonographic measurements

The same physician administered ultrasonographic examinations. A high-resolution US Doppler system (LOGICTM P9, GE Health Care, USA) with a linear transducer (6-15 MHz) was used. When the patient is in the supine position, the transducer was placed in the 9th or 10th intercostal space near the midaxillary line and angled perpendicular to the chest, as validated by Goligher *et al.*[16] Diaphragm thickness (DT) was measured in B mode images (performed at end-expiration) as the distance between the diaphragmatic pleura and the peritoneum. Diaphragm thickening fraction (TF) was defined as the percentage change in diaphragm thickness, and TF was calculated using the M mode (TF = thickness at end-inspiration − thickness at end-expiration/thickness at end-expiration) (Figure 2). Diaphragm measurements were performed at admission to ICU (day 0) and day 3, day 6, and day 9. The patient's skin was marked at the first measurement point to improve repeatability.

Statistical analysis

The data were analyzed using SPSS 26.0 for Macintosh. (SPSS, Armonk, NY: IBM Corp.) The frequency and descriptive statistics were calculated. Descriptive statistics were presented as mean ± SD for continuous numeric variables. One-way ANOVA analyzed the comparisons of numeric data between the three study groups for normally distributed data and the Kruskal-Wallis test for non-normally distributed data. Kolmogorov-Smirnov tests were used for testing normallity. Bonferroni test was used for posthoc tests in ANOVA analysis if there was a statistically significant difference between groups. The categorical data were compared between groups with Chi-Square and Fisher's Exact tests. A logistic regression analysis was conducted to investigate whether the treatment methods impact the patients' invasive mechanical ventilation (IMV) requirement. ROC analysis was performed to determine the US measurements' cut-off values, found as risk factors in logistic regression analysis. The level of statistical significance was set at $p < 0.05$.

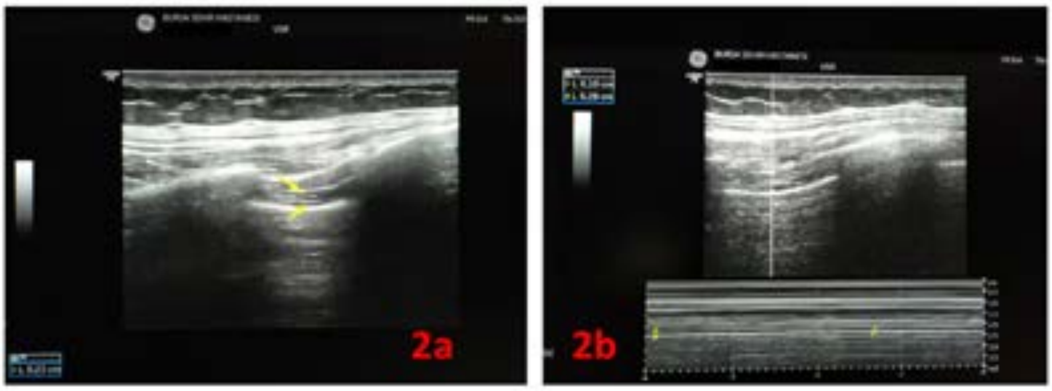

Figure 2. Diaphragm ultrasonography. 2a: measuring diaphragm thickness (DT) in B mode (yellow arrows shows the distance between the diaphragmatic pleura and the peritoneum); 2b: diaphragm thickening fraction (TF) the percentage change in diaphragm thickness in M mode.

RESULTS

A total of 72 patients (24 female, 48 male) with a mean age of 65.7 ± 12.8 years were included in the analysis. The comparisons of the demographic and clinical characteristics of the patients were given in Table 1. The confounding variables such as age, gender, body mass index (BMI) and presence of comorbidities were not different between the groups. The length of stay (LoS) in ICU and mortality were similar between groups. However, there was a statistically significant difference in IMV requirement. In the control group, 83% of the patients underwent IMV, whereas this was significantly lower in the rehabilitation and Kinesio taping group, 63% and 38%, respectively ($p < 0.05$). The mean duration of non-invasive ventilation (NIV) was 12.6 days in the Kinesio taping group, which is remarkably longer than the control group ($p < 0.001$).

Also, the effects of the interventions on diaphragm muscle were compared between groups; the results were shown in Table 1. DT on days six and 9 differed between groups, although there was no difference between admission and day 3. The difference results from the Kinesio taping group and the control group. ($p < 0.05$). Additionally, change in DT is significantly lower in the Kinesio taping group than in the others. ($p = 0.001$). Similarly, the TF of the patients measured on day nine differed between groups ($p < 0.05$). In the Kinesio taping group, TF decreased in 46% of patients, while this ratio is 54% and 75% in the rehabilitation and control groups ($p < 0.05$).

A logistic regression analysis was conducted to investigate whether treatment methods and baseline diaphragm parameters impact IMV requirement after adjusting for other confounding variables such as age, gender, presence of comorbidities, and BMI. Table

Table 1. Comparisons of demographic, clinical characteristics and ultrasonographically measured diaphragm parameters between study groups.

	Group 1 (Rehabilitation) (n: 22)	Group 2 (Rehabilitation +Kinesio taping) (n: 26)	Group 3 (Control) (n: 24)	*P* - value
Age (years)	62.1 ± 13.0	68.3 ± 9.5	70.4 ± 4.6	0.244
Body mass index (kg/m^2)	27.7 ± 2.5	28.5 ± 3.6	28.2 ± 2.7	0.692
Gender (Female/Male)	4/18	10/16	10/14	0.189
Presence of comorbidities (yes/no)	12/10	8/18	8/16	0.192
Length of ICU stay (days)	17.5 ± 5.0	17.3 ± 3.9	23.5 ± 12.9	0.158
Requiring IMV (yes/no)	14/8	10/16	20/4	0.004
Mortality (yes/no)	14/8	12/14	16/8	0.302
Time until IMV (days)	5.5 ± 3.2	12.6 ± 6.2	6.6 ± 3.4	< 0.001*
DT at admission (mm)	2.6 ± 0.4	2.8 ± 0.3	2.7 ± 0.5	0.396
DT at day 3 (mm)	2.6 ± 0.3	2.7 ± 0.3	2.5 ± 0.4	0.356
DT at day 6 (mm)	2.6 ± 0.3	2.8 ± 0.3	2.4 ± 0.3	0.004**
DT at day 9 (mm)	2.7 ± 0.2	2.9 ± 0.5	2.1 ± 0.9	0.013
TF at admission (%)	31.8 ± 5.6	37.4 ± 4.6	36.9 ± 6.1	0.003
TF at day 3 (%)	32.3 ± 6.7	36.1 ± 5.7	34.7 ± 6.5	0.194
TF at day 6 (%)	33.2 ± 6.5	35.9 ± 5.5	32.0 ± 9.3	0.314
TF at day 9 (%)	35.5 ± 2.2	38.2 ± 6.2	28.3 ± 15.8	0.048
Change in DT (mm)	–0.19 ± 0.24	–0.03 ± 0.27	–0.41 ± 0.34	0.001
Change in TF (%)	–2.6 ± 3.8	–2.5 ± 5.6	–1.64 ± 8.9	0.871
DT during study (n)				0.063
Increased	4	10	2	
Unchanged	6	2	4	
Decreased	12	14	18	
TF% during study (n)				0.012
Increased	4	14	4	
Unchanged	6	0	2	
Decreased	12	12	18	

ICU: intensive care unit, IMV: invasive mechanic ventilation, DT: diaphragma thickness, TF: thickening fraction.
Posthoc tests; *Group 1-2: $p = 0.001$, Group 2-3: $p = 0.002$, Group 1-3: $p = 0.762$. **Group 1-2: $p = 0.278$, Group 2-3: $p = 0.003$, Group 1-3: $p = 0.215$.

Table 2. Logistic regression analysis for factors effecting invasive mechanical ventilation requirement.

	Odds ratio	95% CI	*P* - value
Age	1.22	1.00 - 1.49	0.050
Gender (male)	0.001	0.000 - 0.904	0.047
BMI (kg/m^2)	1.008	0.643 - 1.582	0.972
Presence of comorbidity	0.104	0.006 - 1.845	0.123
Treatment group (reference category=control group)			
Rehabilitation	0.001	0.000 - 2.461	0.080
Rehabilitation+Kinesio taping	0.000	0.000 - 1.299	0.057
DT at admission (0.1 mm)	0.439	0.242 – 0.797	0.007
TF % at admission (%1)	0.530	0.324 – 0.867	0.012

BMI: body mass index, DT: diaphragm thickness, TF: thickening fraction, CI: confidence interval. Nagelkerke R2: 0.817.

2 showed the results of the analysis. Age, presence of comorbidities, and BMI were not associated with IMV. However, male gender, DT, and TF were significant predictors for IMV. Every 0.1 mm increase of DT and every 1% increase of TF decreases the risk of IMV 0.4 (95% CI: 0.2-0.7, $p < 0.05$) and 0.5 fold (95% CI: 0.3-0.8, $p < 0.05$), respectively.

A ROC analysis was performed to determine cut-off values of the diaphragm parameters that impact the need for IMV. The results were given in Table 3. Patients with DT under 2.85 mm (AUC: 0.804, sensitivity: 71.4%, specificity: 86.4%, PPV: 76.9%, NPV: 82.6%) and TF under 37.95% (AUC: 0.802, sensitivity: 64.3%, specificity: 90.9%, PPV: 81.8%, NPV: 80%) were more likely to need IMV ($p < 0.001$).

DISCUSSION

Early rehabilitation approaches are associated with advanced muscle strength, physical function, and quality of life in ICU survivors. Rehabilitation interventions have benefits on the duration of mechanical ventilation and length of hospital or ICU stay. Also, they may help to reduce physical and mental health complications. Rehabilitation interventions are reported to be safe and feasible in ICU.[5,11,17] Although early rehabilitation's efficacy is apparent, it remains unclear if rehabilitation is appropriate for the early stages of COVID-19.[4] The data about rehabilitation in COVID-19 is limited to expert opinions.[7,8,18] Controversially, recommendations suggest pulmonary rehabilitation in acute inpatient management can be safe and may be cautiously approached.[6-8] In Özyemişci's study[8], which investigated the effects of rehabilitation in acute respiratory distress syndrome patients with COVID-19 in the ICU, no beneficial effects of rehabilitation on mortality, length of stay in the ICU, IMV duration, and muscle strength were reported. On the other hand, Li *et al.*[19] showed that the early rehabilitation program increased respiratory muscle strength in patients with COVID-19. In our study, the length of stay in the ICU and mortality in the group that did not receive rehabilitation were similar to those that received rehabilitation. Still, the need for IMV was significantly higher.

Studies report that Kinesio tape improves extremity muscle functions due to increased proprioceptive stimulation.[13,20-22] There are limited results for the efficacy of Kinesio tape on respiratory muscles. In a study investigating the effects of Kinesio tape on pulmonary functions and aerobic capacity in sedentary individuals, it was observed that spirometry parameters and shuttle run test distance increased in the Kinesio taping group.[14] In another study, pulmonary functions, perceived severity of dyspnea and fatigue, and functional capacity were improved by Kinesio tape in patients with chronic obstructive pulmonary disease (COPD). However, no significant improvement in respiratory muscle

Table 3. ROC analysis for diaphragma parameters at admission to hospital.

	AUC	95% CI	*P* - value	Cut-off value	Sensitivity	Spesificity	PPV	NPV
DT (mm)	0.804	0.702-0.905	< 0.001	2.85 mm	71.4%	90.9%	81.8%	80%
TF %	0.802	0.697-0.906	< 0.001	37.95%	64.3%	86.4%	76.9%	82.6%

AUC: area under the curve, CI: confidence interval, PPV: positive predictive value, NPV: negative predictive value, DT: diaphragm thickness, TF: thickening fraction.

strength was evaluated with maximal respiratory mouth pressures.[20] The need for IMV (38%) was lowest in our study group that received rehabilitation along with Kinesio tape.

Only one study demonstrated the effects of Kinesio tape on respiratory muscle thickness in patients who underwent IMV. The results of this study showed that the decrease in DT on Kinesio tape applied side is less than the side in which Kinesio tape was not used. However, this effect did not continue after the sixth day.[15] The method and cohort of this study are different from our study. In our study, Kinesio tape was applied to the intercostal muscles of patients who underwent IMV. Our study found that DT decreases in all treatment groups, but the decrease is less in the Kinesio taping group than in other groups. Therefore, we consider that Kinesio tape can be applied in addition to conservative rehabilitation methods to preserve DT, which is known to be a prognostic predictor in the ICU.

Diaphragm weakness is strongly associated with disease severity and poor prognosis.[23] In daily practice in ICU, US is recommended to be a reliable and easily applicable tool to evaluate diaphragm function.[9] Diaphragm weakness detected during ICU admission is associated with higher mortality.[9,24] The risk of hospital readmission after discharge is more likely to be seen in patients with respiratory muscle weakness.[25,26] Previous studies also reported that decreased DT was associated with prolonged IMV and LoS.[26,27] In our study, DT was found to be a risk factor for respiratory failure, and we determined a cut-off value to predict IMV requirement. Supporting our results, the presence of diaphragmatic dysfunction (defined as the change in DT during spontaneous breathing less than 20%) increases the risk of NIV failure 4.4 fold in patients with acute exacerbation of COPD admitted to ICU.[28]

There are only a few reports for evaluating diaphragm dysfunction in patients with COVID-19.[10,29,30] In a case report of a patient at risk of respiratory failure, measurements of DT and TF by the US indicated diaphragm dysfunction before worsening in arterial blood gas analysis.[29] So, the importance of US evaluation can be emphasized. In a recent study; evaluating TF to detect patients at risk of continuous positive airway pressure (CPAP) failure and require IMV, lower values of TF are shown to be associated with CPAP failure and requirement of IMV. The best threshold value for TF was 21.4%, with a sensitivity and specificity of 94.4% and 88.9%, respectively.[30] Our study found a higher threshold value with a lower sensitivity but similar specificity for TF. Overall, these findings support our study's results. Our study's findings suggest that early rehabilitation and Kinesio tape can effectively improve diaphragm muscle thickness and reduce the need for IMV in patients with severe COVID-19 pneumonia.

Our study is the first to report the efficacy of early rehabilitation and diaphragm Kinesio tape in patients with COVID-19 who underwent NIV and evaluate the effects by ultrasonographically measured diaphragm parameters. Besides its effectiveness, we also emphasize that early rehabilitation in the ICU seems safe if hygienic conditions, PPE precautions, and close monitoring are provided. We did not encounter a co-infection or an adverse effect. Nevertheless, further studies are required for confirmation.

There were some limitations of our study. First, the sample size was relatively small, particularly for the subgroups. Additionally, we examined patients after admission to ICU, and any information after discharge was not recorded. So, the efficacy should be investigated in the early stages of pneumonia before the patient develops ICU requirements and long-term effects should be monitored by follow-ups after discharge.

CONCLUSIONS

Baseline DT evaluated with the US easily at the bedside in ICU can be used to predict patients at high risk of IMV. Patients more likely to develop respiratory failure should receive inspiratory muscle training exercises combined with general rehabilitation principles. Also, the rehabilitation protocol should include Kinesio tape on respiratory muscles applied with muscle facilitation technique. The benefits of rehabilitation and Kinesio tape in patients with severe COVID pneumonia in the ICU at early stages need to be confirmed by prospective, randomized, controlled clinical trials in large study populations. Furthermore, the effectiveness of Kinesio taping on respiratory muscles should be investigated in patients with respiratory failure caused by various reasons apart from COVID pneumonia.

Conflict of Interest

The author(s) declared no potential conflicts of

interest with respect to the research, authorship, and/or publication of this article.

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Ethical Approval

The protocol of the study was approved by the Medical Ethics Committee of Health Sciences University , Bursa City Hospital, Bursa, Turkey. (Decision number: 2023-3/12, date: 16.07.2020).

Authors' Contribution

Study Conception: SA, ST, TD; Study Design: ST, GÇ, SA; Supervision: ST, GÇ, TD; Fundins: GÇ, TD; Materials: ST, SA; Data Collection and/or Processing: GÇ, TD; Analysis and/or Data Interpretation: SA, GÇ; Literature Review: TD, GÇ; Critical Review: TD, GÇ; Manuscript preparing: SA, ST.

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