Brief Communication

Feasibility of whole-body vibration as an early inpatient rehabilitation tool after lung transplantation – a pilot study


Abstract: Objective: Optimal rehabilitation programs are essential in the early phase after lung transplantation (LTx). Whole-body vibration (WBV) may be a novel approach in rehabilitation that has not yet been investigated in these patients.

Patients and methods: Ten patients in the early postoperative phase after LTx after discharge from the intensive care unit (ICU) were included in the study. WBV training was performed until transfer to a rehabilitation center. Six-minute walk distance (6-MWD), pulmonary function, maximal workload, and quality of life (SF-36) were assessed at the beginning and after completion of the training program.

Results: Patients revealed a significant improvement of the 6-MWD, the vital capacity (VC), the maximal workload, and in quality of life (SF-36) were assessed at the beginning and after completion of the training program.

Conclusion: WBV in lung transplant recipients after discharge from ICU is safe and feasible. WBV may effectively support rehabilitation programs improving pulmonary function and quality of life.

Rehabilitation programs are an essential part of therapy after lung transplantation (LTx) (1). Severe structural and functional alterations are abundant in lung recipients due to underlying various lung diseases (2, 3). Further, in the early postoperative phase after transplantation intensive care unit (ICU)-related weakness and muscle dystrophy is a highly prevalent problem (4, 5). Early active muscle training would be an ideal treatment to attenuate this ICU-acquired weakness. However, in the early post-transplantation phase, the majority of patient is unable to participate in active mobilization training.

Whole-body vibration (WBV) is a novel exercise training modality, performed on a vibrating platform, creating accelerations that are transmitted to the body. WBV elicits physiological responses similar to other modes of physical activity (6). Recently, several studies could demonstrate beneficial effects of WBV in patients with COPD and cystic fibrosis on pulmonary function and muscle strength (7–9). Further, WBV has been established in patients with neurological diseases to improve postural control and for patients with osteoporosis to enhance bone mineral density (10, 11).

As optimal rehabilitation programs are essential in the early postoperative phase after LTx, WBV may be a novel approach in rehabilitation for these patients. As a proof of concept, we investigated in
this study the effects of WBV, in particular regarding safety and feasibility, in the early postoperative phase in patients after LTx.

**Methods**

**Patient population**

From September 2014 to April 2015, a total of 26 patients underwent lung transplant surgery in the University Hospital Grosshadern in Munich, Germany (Fig. 1). Sixteen consecutively eligible patients after LTx were screened for the study. LTx patients were considered for participation during hospitalization in the early postoperative phase after discharge from the ICU unit before transfer to a rehabilitation center. Six patients did not participate due to personal reasons. Further inclusion criteria included minimum age 18 yr and written informed consent. Exclusion criteria were severe infection or acute rejection, contraindication or inability for physical workout, impaired cognitive function limiting the ability to answer the questionnaires.

The intervention program consisted of a WBV training with the “Wellengang excellence” platform (Wellengang GmbH, Otisheim, Germany). The maximum amplitude of the “Wellengang excellence” platform is ±4.5 mm, and the platform frequency is 1–28 Hz. The training program was started on the first day after discharge from the ICU (after fulfilling the inclusion criteria and absence of exclusion criteria) and was continued until transfer to a rehabilitation center. The training was performed under supervision of a respiratory therapist on five d per week, 10 min per day. The frequency (up to 10 Hz) and body

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**Table 1. Patient characteristics**

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>49.8 ± 11.4</td>
</tr>
<tr>
<td>Minimum</td>
<td>32</td>
</tr>
<tr>
<td>Maximum</td>
<td>62</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>5</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
</tr>
<tr>
<td>Time since LTx; stay on ICU (d)</td>
<td>13.0 ± 10.4</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
</tr>
<tr>
<td>Maximum</td>
<td>31</td>
</tr>
<tr>
<td>Underlying disease</td>
<td></td>
</tr>
<tr>
<td>Idiopathic pulmonary fibrosis</td>
<td>3</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>3</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
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<tr>
<td>Sarcoidosis</td>
<td>1</td>
</tr>
<tr>
<td>Systemic sclerosis</td>
<td>1</td>
</tr>
<tr>
<td>Procedure type of LTx</td>
<td></td>
</tr>
<tr>
<td>Single lung transplantation</td>
<td>2</td>
</tr>
<tr>
<td>Double lung transplantation</td>
<td>8</td>
</tr>
<tr>
<td>Duration of training program (d)</td>
<td>10.3 ± 2.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>8</td>
</tr>
<tr>
<td>Maximum</td>
<td>13</td>
</tr>
</tbody>
</table>

Data expressed in mean ± standard deviation. LTx, lung transplantation; ICU, intensive care unit.

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*Patients were transferred to another institution due to prolonged weaning (n = 2) and critical illness polyneuropathy (n = 2). Patients underwent surgical revision (n = 2) or were readmitted to ICU before screening, that is, within the 24 h after admission to the general ward. ICU, intensive care unit.

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**Fig. 1.** Enrollment and screening.
starting position (standing or sitting) were chosen according to the individual patient’s capabilities. The intervention was static without further activity. All parameters described in the study were determined at the beginning and after completion of the training program.

The study protocol was approved by the ethics committee of the medical faculty of the Ludwig Maximilians University, Munich, Germany.

Six-minute walk test
The distance covered in six min walk distance (6-MWD) was measured according to the American Thoracic Society statement (12).

Lung function testing
The following lung function parameters were included in the study: forced expiratory volume

Fig. 2. Pulmonary functional parameter at the beginning and after completion of the training program (WBV, whole-body vibration). (A) 6-MWD, six-min walk distance. (B) Peak cough flow. (C) FEV1, forced expiratory volume. (D) VC, vital capacity.
(FEV<sub>1</sub>), vital capacity (VC), and peak cough flow (PCF).

Maximal workload
The maximal workload was determined with the “KMP Newton” platform (KMP Newton GmbH, Stein, Germany).

Short-Form 36 Health Survey (SF-36)
The SF-36 is a multipurpose, short-form health questionnaire with 36 items. It measures eight aspects of health: physical functioning, social functioning, role limitation attributed to physical problems, role limitation attributed to emotional problems, mental health, energy and fatigue, pain, and overall health (general medical health). For each variable, the item scores are coded, added up, and transformed into a scale from 0 (worst possible health) to 100 (best health). The German validated version 1.0 of the SF-36 was used.

Specific WBV questionnaire
After the training program all patients had to answer the following four questions: Did you benefit from the WBV training? Did the training support your muscle building? Did the training support the secretion mobilization? Was the training program comfortable for you? The responses were scored from 1 (strongly disagree) to 5 (strongly agree).

Statistical analysis
Results are expressed in mean ± standard error of mean (SEM). Patient characteristics are expressed in mean ± standard deviation as indicated. Data were evaluated for normal distribution by the Anderson–Darling test. All values were significantly different from normal distribution. Therefore, Mann–Whitney U-test was used for statistical testing. Values of p < 0.05 were considered statistically significant.

Results
Patient characteristics
The patient characteristics are summarized in Table 1.

6-MWD findings
The subjects had a significantly improved 6-MWD after completion of the training program (before WBV: 132.3 ± 31.2 m; after WBV: 255.5 ± 43.3 m; p < 0.05). The gain in 6-MWD was 132.2 ± 20.0 m (Fig. 2A).

Findings in lung function testing
The PCF was improved after completion of the training program, but did not reach statistical significance (before WBV: 215.6 ± 31.1 L/min; after WBV: 291.2 ± 32.2 L/min; p = 0.11) (Fig. 2B).

Fig. 3. (A) SF-36 questionnaire with the following aspects of health: (1) physical functioning; (2) role limitation attributed to physical problems; (3) pain; (4) general medical health; (5) energy and fatigue; (6) social functioning; (7) role limitation attributed to emotional problems; and (8) mental health. Scale from 0 (worst possible health) to 100 (best health). White: before whole-body vibration (WBV). Black: after WBV. (B) Response to the following questions: (1) Did you benefit from the WBV training? (2) Did the training support your muscle building? (3) Did the training support the secretion mobilization? (4) Was the training program comfortable for you? Scale from 1 (strongly disagree) to 5 (strongly agree).
The gain in PCF was 75.6 ± 39.0 L/min. The FEV₁ was slightly improved, but without statistical significance (before WBV: 1.78 ± 0.14 L; after WBV: 2.04 ± 0.18 L; p = 0.26) (Fig. 2C). The VC was significantly increased after the training program (before WBV: 1.95 ± 0.08 L; after WBV: 2.51 ± 0.25 L; p < 0.05). The gain in VC was 0.51 ± 0.24 L (Fig. 2D).

Outcome in maximal workload
The maximal workload (measured in Watt) was significantly improved after completion of the training program (before WBV: 62.8 ± 16.3 Watt; after WBV: 135.4 ± 32.2 Watt; p < 0.05) (Fig. 2E). The maximal workload (measured in Watt/kg) was significantly improved after completion of the training program (before WBV: 0.99 ± 0.31 Watt/kg; after WBV: 2.38 ± 0.86 Watt; p < 0.05) (Fig. 2F).

Findings in the SF-36 questionnaire
Among the eight measured aspects of health, only the scale “general medical health” showed a significant improvement after completion of the training program. Except the scale “pain,” all other aspects were improved, but did not reach statistical significance (Fig. 3A).

Results in the specific WBV questionnaire
The four specific questions regarding WBV revealed a positive response of the individual subjects (Fig. 3B).

Discussion
To the best of our knowledge, this is the first study investigating the effects of WBV in the early postoperative phase after LTx. The most important finding of this proof of concept study is that WBV as an early rehabilitation tool is safe and feasible in these patients. In a short-term follow-up, we could demonstrate a significant improvement of the 6-MWD, the VC, the maximal workload, and the quality of life.

A growing amount of studies has reported the benefit of WBV for patients with multiple sclerosis (13), stroke (14), cystic fibrosis (15), and COPD (6, 9). Similar to our findings, other studies in patients with COPD could also demonstrate an improvement in the 6-MWD, in pulmonary parameters, and in quality of life (6, 7, 9). These effects may be the result in particular from an increase of muscle strength and muscle mass. Training with WBV is known to evoke muscle contraction of the lower limb and the entire trunk (16). It has been shown that WBV induces hormonal and neuromuscular responses similar to resistance training (17). On the molecular level, WBV was demonstrated to increase the expression of transcription factors supporting the reconstitution of muscle strength (7). In accordance with other studies, we could demonstrate the WBV is safe and did not cause any adverse events.

The WBV training cannot be considered for all patients after LTx, because there are several barriers to initiating this therapy. Among those, inability for physical workout, especially due to critical illness polyneuropathy after long stay on the ICU, has to be mentioned. Further, some patients subjectively feel too weak or too anxious for this kind of therapy.

There are some limitations of our study. The WBV training program was performed only in a small number of patients without a matched control group. Therefore, we do not have a way to know how much of the improvement of the measured parameters is impacted by WBV, as these parameters typically increase postoperative regardless. However, this study is meant to be a proof of concept study, and further randomized studies are needed to confirm our findings.

Acknowledgements
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References


