INTRODUCTION

Maintenance hemodialysis (HD) patients have decreased muscle mass, reduced strength and exercise tolerance, and can easily become fatigued. Exercise training is an essential part of ameliorating or preventing these conditions. However, HD patients often find it difficult to perform or continuously practice exercise programs. Exercise training using an electric ergometer (Elex), which places little burden on the patient and allows only continuous passive exercise during HD, has been implemented in a large number of facilities. Although Elex allows exercise in HD patients, including those with minimal ability, it may not reach an effective level of exercise intensity compared with the traditional variable-load type of ergometer (Tex). This is because Tex ergometers allow patients to adjust their exercise training.

Objective: Hemodialysis (HD) patients have lower fitness levels than healthy subjects because of various structural, metabolic, and functional abnormalities secondary to uremic changes in skeletal muscles. Aerobic and resistance exercises are beneficial in improving not only physical function, including maximal oxygen uptake and muscle strength, but also anthropometrics, nutritional status, and hematologic indices. The use of electric ergometers that place light loads on patients has been implemented at many dialysis facilities in Japan. However, reports comparing the effects on body function of electric and variable-load ergometers are few. This study aimed to compare electric ergometers and variable-load ergometers in terms of exercise outcomes in HD patients.

Methods: A total of 15 ambulatory HD patients were randomly divided into two groups: the variable-load ergometer group (n=8) and the electric ergometer group (n=7). HD patients exercised at a level based on their physical function three times a week for 12 weeks.

Results: After the 12-week intervention period, only the variable-load ergometer group experienced significant increases in lower extremity muscle strength and exercise tolerance.

Conclusion: This study confirmed that conventional aerobic training and electric bike exercise during HD were efficacious and safe without causing sudden hypotension or any other side effects. However, exercise using a variable-load ergometer may be more effective than exercise using an electric bike in improving the physical function of HD patients. Exercise using a variable-load ergometer elicited specific whole-body and local effects.
to the appropriate intensity and are beneficial in improving physical function. However, Tex users are at risk for muscle strain, arthralgia, cardiovascular events, sudden drops in blood pressure, and difficult vascular access. Therefore, in this study, we investigated the effect of these two different forms of bicycle exercise on physical function and the safety of exercise training during HD.

METHODS

We performed a prospective randomized clinical trial involving 15 ambulatory patients undergoing outpatient HD therapy three times a week at Asao Clinic in Kawasaki, Japan (Table 1). The exclusion criteria were unstable angina, pulmonary hypertension, and any other reasons determined by the principal investigator. The subjects comprised eight men and seven women and were randomly and electronically assigned to either the Tex group or the Elex group using a static allocation strategy. Eight subjects were assigned to the Tex group and seven were assigned to the Elex group. The primary disease was diabetic nephropathy in four subjects, chronic glomerulonephritis in seven subjects, nephrosclerosis in two subjects, and others in two subjects. The mean age was 71.5 ± 1.6 years and the mean duration of HD was 10.7 ± 1.9 years.

All the subjects participated voluntarily and provided written informed consent. This study was approved by the Institutional Review Board of Tsukuba University of Technology (approval no. 05/02/2015) and was registered with the UMIN clinical trial registry (UMIN-CTR) (ID000024409) in accordance with CONSORT 2010.

Variable-load Ergometer Exercise Method

The subjects set the time and variable load to 11–13 on the Borg Rating of Perceived Exertion (RPE) scale, i.e., in the fairly light to somewhat hard range. They performed up to 1 h of exercise during the first half of HD (Fig. 1) three times a week for 12 continuous weeks. The exercise duration and loads were set according to the physical function of each patient. During exercise, the subjects maintained their heart rate within 40 beats/min above their resting heart rate.

Electric Ergometer Exercise Method

The subjects set the time and speed that allowed them to maintain Borg 11–13 levels of RPE. They performed up to 1 h of exercise during the first half of HD (Fig. 2) three times...
a week for 12 continuous weeks. The exercise duration was set according to the physical function of each patient. During exercise, the subjects maintained their heart rate within 40 beats/min above their resting heart rate.

Measurement Methods

Before and after 12 weeks of intervention, we obtained the following test results from the subjects’ medical records: muscular power of the quadriceps (MPQ), 30-s chair stand test (CS30), timed up and go test (TUG), 6-min walking distance (6MWD), dialysis efficiency, and biochemical tests.

Measurement of the Muscular Power of the Quadriceps (MPQ)

Muscle strength was measured using a handheld dynamometer with belt stabilization (GT-300; OG Wellness Technologies Co., Ltd.). The maximum muscle strength during isometric knee extension was measured once on the left leg and once on the right leg; the larger of the two measurements was used.1)

30-S Chair Stand Test (CS30)

The subjects were asked to sit on a 40-cm-high chair with their legs apart at shoulder width. They were then instructed to repeatedly stand up and sit down as many times as possible during a 30-s period. Measurements were taken twice with a rest period in between; the higher number was used for analysis.2)

Timed Up and Go Test (TUG)

The patients were taken to a room in the clinic where they were asked to sit on a chair. When given the signal, they stood up, walked forward as fast as possible for three meters, rounded a cone, and returned to a seated position on the chair. The time required to perform these tasks was measured twice; the mean value was used as the TUG measurement.3)

Six-minute Walking Distance Measurement (6MWD)

The patients were taken to a hallway in the clinic. The distance that they were able to cover while walking for 6 min was measured in accordance with the standard protocol of the American Thoracic Society.4)

Statistical Analysis

All data were analyzed using IBM SPSS Statistics version 24 (IBM Corp, Armonk, NY, USA), which included descriptive and inferential statistics packages. For parametric data, comparisons of pre- and post-intervention values at two time points were analyzed using repeated measures analysis of variance. Post-hoc tests were performed using the Tukey–Kramer test or Scheffe’s test depending on the parameters. The unpaired $t$-test and the Mann–Whitney $U$-test were used to compare the pre-intervention values between the Tex group and the Elex group. Sample sizes were calculated using G-Power version 3.1 (Franz, Universitat Kiel, Germany), using an alpha value of 0.05 and a power of 80%.5) All results are given as the mean ± standard deviation, and significance was set at $P<0.05$.

RESULTS

There were no differences between the groups before the intervention in terms of the demographic data shown in Table 1. The parameter values before and after 12 weeks of intervention are shown in Table 2. Intergroup differences both prior to and after 12 weeks of exercise intervention were observed for 6MWD ($P<0.05$). Moreover, post-intervention differences between the Tex and Elex groups were observed for MPQ. The other post-intervention parameters, apart from 6MWD and MPQ, showed no significant differences between the Tex and Elex groups. Biochemical test results in both groups were not significantly affected by the intervention. Compared with the pre-intervention values, the post-
Table 2. Changes after 12 weeks of intradialytic exercise with traditional or electric exercise bikes

<table>
<thead>
<tr>
<th></th>
<th>Tex group (n=8)</th>
<th>Elex group (n=7)</th>
<th>Interaction P value</th>
<th>Intergroup comparison P value</th>
<th>The effect of exercise P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>DW (kg)</td>
<td>52.4 ± 2.8</td>
<td>52.4 ± 2.5</td>
<td>51.3 ± 5.4</td>
<td>51.4 ± 2.6</td>
<td>n.s.</td>
</tr>
<tr>
<td>Kt/V (ml/min)</td>
<td>1.7 ± 0.1</td>
<td>1.6 ± 0.2</td>
<td>1.6 ± 0.2</td>
<td>1.6 ± 0.1</td>
<td>n.s.</td>
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<tr>
<td>TP (g/dl)</td>
<td>6.8 ± 0.2</td>
<td>6.8 ± 0.3</td>
<td>6.7 ± 0.2</td>
<td>6.8 ± 0.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Hb (g/dl)</td>
<td>10.8 ± 0.2</td>
<td>10.8 ± 0.2</td>
<td>11.3 ± 0.5</td>
<td>11.0 ± 0.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>Non-HDL-C (mg/dl)</td>
<td>123.4 ± 7.0</td>
<td>123.4 ± 6.6</td>
<td>124.6 ± 16.9</td>
<td>128.3 ± 7.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>MPQ (kgf)</td>
<td>26.2 ± 1.5</td>
<td>28.1 ± 1.6</td>
<td>27.6 ± 1.5</td>
<td>19.3 ± 2.8</td>
<td>0.025</td>
</tr>
<tr>
<td>CS-30 (no. of times)</td>
<td>12.8 ± 0.9</td>
<td>14.8 ± 0.7</td>
<td>11.7 ± 2.4</td>
<td>14.4 ± 2.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>7.5 ± 0.6</td>
<td>6.3 ± 0.3</td>
<td>7.9 ± 1.1</td>
<td>8.9 ± 1.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>6MWD (m)</td>
<td>479.5 ± 34.4</td>
<td>549.5 ± 34.7</td>
<td>389.1 ± 75.8</td>
<td>390.6 ± 79.2</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± standard deviation.

n.s.: not significant, pre: pre-intervention, post: post-intervention, DW: dry weight, Kt/V: HD efficiency, TP: total protein, Hb: hemoglobin, non-HDL-C: non-high-density lipoprotein cholesterol, MPQ: muscular power of the quadriceps, CS-30: 30-s chair stand test, TUG: time up and go test, 6MWD: 6-minute walking distance test.
intervention MPQ values significantly changed from 26.2 ± 1.5 kgf to 28.1 ± 1.6 kgf (P=0.031) in the Tex group and from 27.6 ± 1.5 kgf to 19.3 ± 2.8 kgf (P=0.046) in the Elex group; interaction was observed (P=0.025). The 6MWD significantly changed from 479.5 ± 34.4 m to 549.5 ± 34.7 m (P=0.028) in the Tex group but was unchanged by exercise in the Elex group.

**DISCUSSION**

To the best of our knowledge, this study was the first to compare Tex and Elex in HD patients. The results of the study showed that Tex increased both MPQ and the exercise tolerance (6MWD) of patients on HD, probably because Tex is an aerobic exercise that at the same time allows resistive exercise of the leg muscles. Consistent with our results, 12 weeks of Tex was previously reported to be effective in increasing MPQ.6) Although the effects were not significant, after intervention in the Tex group, the subjects’ balance ability (as measured by the TUG) and the endurance of the quadriceps (as measured by the CS-30) tended to increase (P=0.07). The small number of subjects in this study, as well as the relatively short intervention period and low exercise intensity, might have explained the absence of significant effects on CS-30 and TUG.

The Elex system provides passive exercise, which has effects that are similar to those of continuous passive motion (CPM) devices that are utilized after orthopedic surgery. CPM is reportedly effective for pain alleviation through improvement of joint range of motion and circulation and it also promotes the healing of wounds.7) However, few studies have reported on its relationship with increased muscle strength.8) Although the present study did not show an intergroup difference in pre-intervention MPQ, it showed a significant post-intervention decrease in MPQ in the Elex group, compared with the Tex group. However, there were no significant differences between the groups in terms of the post-intervention CS-30, which indicates quadriceps endurance, or TUG, which indicates balance ability. Based on these results, Elex may be used as a low-burden exercise method for the purpose of maintaining endurance. However, we believe that an exercise regimen should be both low-burden and effective; rather than Elex alone, a therapy program consisting of both Elex and resistance exercises should be utilized.

According to previous reports,9, 10 the differences between Tex and Elex include the effectiveness of resistance exercises in increasing muscle strength and are based on the fact that improvement of endurance by strengthening exercises is more effective when the effects of both muscle strengthening and endurance strengthening exercises are combined. The results of the present study indicated that Tex had both muscle strengthening and endurance strengthening effects. Elex, on the other hand, had only an endurance maintenance effect.

In this study, we observed no adverse events, such as a sudden drop in blood pressure, muscle pain, changes in venous pressure during HD, or problematic vascular access, in either group during the intervention period. The results of the biochemical tests suggested that the exercises used in this study had no effect on nutritional factors, anemia, or cholesterol levels. Previous research has shown that exercise during HD did not cause adverse events5) and even prevented new cardiovascular events.12) Exercise has been reported to improve dialysis efficiency,13) but the results of this study showed no such effect. Possible reasons for this are that the subjects of the present study were dialysis patients who resided at home, meaning that they were in a stable environment. Moreover, because their pre-intervention Kt/V levels were at least 1.5, further increases in this value were unlikely.14) Furthermore, it is possible that the exercise intensity in the current study was insufficient to achieve the desired effect. In this study, we utilized the bike exercise training protocol described by Dobsak et al.6) However, the subjects had a mean age of 71.5 ± 1.6 years and an underweight body mass index of 20.5 ± 0.5. Therefore, our subjects probably had a lower muscle mass and may have been more prone to fatigue than the European subjects of the previous study. As a result, the exercise intensity and duration may have been insufficient. We estimated the optimum sample size for future studies based on our 6MWD results, because 6MWD is considered the parameter most amenable to change. We found that n >48 is optimum, and we should assign the patients in future studies to the two treatment groups using web-based minimization techniques. Furthermore, a resistance-training program that is more suitable for elderly Japanese subjects is required to investigate further the effectiveness of these exercise methods.

**CONCLUSION**

Bike exercise during HD was safe, regardless of the exercise mode. Tex was more effective than Elex in improving the physical function of patients on HD.
ACKNOWLEDGEMENTS

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest in this study.

REFERENCES


