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Original Article

Effects of an additional resistance training intervention in hemodialysis patients performing long-term ergometer exercise during dialysis

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Abstract. [Purpose] To verify the effect of a 12-week additional resistance training intervention in patients on hemodialysis who had been performing supine ergometer exercises alone during dialysis. [Participants and Methods] Overall, 18 patients undergoing hemodialysis were included. A 12-week intervention with additional resistance training was conducted in hemodialysis patients who had been performing supine ergometer exercise for 30 min during dialysis for over >3 months. Physical function before and after the period of bicycle ergometer exercise alone and before and during the additional intervention was compared. Resistance training consisted of 1–3 sets per day of five different exercises for the large muscle groups of the upper and lower limbs. [Results] The results of the 6-min walk test improved significantly after the additional intervention. The average driving distance in the supine ergometer exercise during the additional intervention was identified as an associated factor. [Conclusion] The addition of the resistance training to long-term supine ergometer exercisers improved walking endurance. When supine ergometer exercise alone does not change physical function, the additional use of resistance training subsequently may have a positive effect on walking endurance.

Key words: Renal rehabilitation, Supine ergometer exercise, Resistance training

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INTRODUCTION

The number of elderly patients on dialysis is increasing worldwide. Effective exercise is important because an increasing number of elderly people suffer from sarcopenia due to aging and decreased physical activity. According to the United States Renal Data System, the prevalence of dialysis among the general population was highest in 2018 in Taiwan (3,429 per million of population [pmp]), followed by Japan (2,591 pmp), Thailand (1,885 pmp), Singapore (1,854 pmp), the United States (1,699 pmp), and South Korea (1,618 pmp)[1]. In most of these countries, patients with end-stage renal disease tended to be older than 75 years of age. Furthermore, in addition to the aging of hemodialysis patients, the decline in physical functions of elderly patients undergoing hemodialysis has become an important issue worldwide. In a nine-year follow-up study of hemodialysis patients in Japan, the prevalence of sarcopenia in patients on dialysis is reported to be 40%, with a significantly high mortality rate[2]. Several studies have shown positive effects of exercise therapy on patients undergoing dialysis. Liu et al. reported that aerobic exercise improves physical function in patients undergoing dialysis[3]. A meta-analysis of on-dialysis

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exercise in patients showed that the exercise improves dialysis efficiency and maximal oxygen uptake[4]. Studies on resistance training during dialysis have reported improved physical activity without significant improvements in muscle mass[5]. Exercise therapy for patients undergoing hemodialysis has been suggested to improve exercise tolerance, walking ability, and physical quality of life[6], with a combination of aerobic and resistance exercises[6, 7]. Our research team has previously conducted aerobic exercise interventions using a supine ergometer during hemodialysis[8, 9]. However, we did not conduct any resistance training intervention. The effectiveness of adding resistance training to patients on hemodialysis who have been only on aerobic exercise using supine ergometer has not yet been confirmed. We hypothesized that the physical condition of patients reaching a plateau by the aerobic exercise alone can be improved by incorporating resistance exercise.

This study examined the effect of a 12-week additional intervention combined with resistance training on patients undergoing hemodialysis who had been performing supine ergometer exercises during dialysis for more than 3 months.

PARTICIPANTS AND METHODS

The research participants were briefed on the research and ethical considerations regarding the study before it began. These explanations were provided in written and oral forms. Study participation inclination was confirmed by the participants by signed the consent form. This study was conducted in accordance with the principles of the Declaration of Helsinki. Approval was obtained from the Research Ethics Committee of Mizuho Medical Corporation before the start of the study (approval number: 16).

This study had (A) period of only supine ergometer exercise during dialysis and (B) period of additional combined intervention of supine ergometer exercise during dialysis plus resistance exercise before dialysis. A period was longer than 3 months, and most of the participants had been performing supine ergometer exercise during dialysis for years prior to the A period and had a long exercise history. The B period was set at 12 weeks. We compared the changes in physical function data over time at three assessment times: before and after the A and B periods (Fig. 1). The participants were 23 outpatients (21 males and 2 females, age 63 ± 11 years) who volunteered to participate in an intervention study related to dialysis and exercise from the 132 outpatients undergoing hemodialysis at the dialysis center of Mizuho Hospital. Participants were recruited through an open recruitment process in which the content of the study was posted in the dialysis unit and applicants were invited to participate.

Physical functions of participants were measured three times before and after the A and B periods. Measurements of physical function included grip strength, knee-extension muscle strength, one-leg standing time, timed up-and-go test (TUG), and 6-min walk distance test (6MD). Grip strength of both hands was measured twice with participants in the standing position, and the maximum value was taken as the representative value. Knee-extension muscle strength was measured using a handheld dynamometer (μ-TAS F1; Anima Corporation, Tokyo, Japan). Measurements were taken with participants in the sitting position on a training bed, with the upper limbs folded in front of the chest, the belt attached to the foot of the bed to secure the lower limbs, and the attachment placed on the front of the lower limb. The measurement results were expressed in kilograms and divided by the distance from the knee axis to the attachment (kg/m). The one-leg standing time was measured from the time when both upper limbs were placed on the hips and one leg was raised from the floor until the raised lower limb touched the floor or the contralateral lower limb. The maximum measurement time for the one-leg standing time was 60 s. The 6MD was measured as the maximum distance walked in 6 min, although rest was allowed if the participant became fatigued during that time.

Supine ergometer exercise during dialysis was performed for 30 min during dialysis. The optimal exercise intensity was set for each participant using the Borg scale. The Borg scale is the rate of perceived exertion[10], and the optimal intensity in

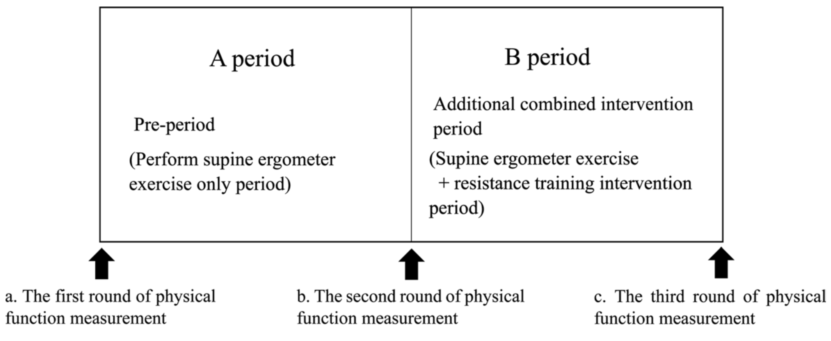

Fig. 1. Study period.
The study period consists of A period, in which only supine ergometer exercises are performed, and B period, in which resistance training is added to the supine ergometer exercises. Three measurements are conducted: before A period, between A and B periods, and after B period.

this study was set 11–12 of Borg scale. The exercise intensity was set by the weight of the pedals and the number of rotations. Regarding the supine ergometer exercise, a variable-load supine ergometer (Terasu Ergo III, Showa Denki Co., Ltd., Osaka, Japan) or electric cycle machine (Escargot, Meisei Co., Ltd., Tokyo, Japan) was used. The exercise intensity was set at 11 subjective exercise intensities, and respiratory fatigue and lower limb fatigue during supine ergometer exercise were measured using the Borg scale. Blood pressure and pulse rate were measured before and after the supine ergometer exercise for risk management.

The additional resistance training performed was an exercise before dialysis using five different rubber bands (Spoband; YKC Co., Tokyo, Japan). The intensity of the rubber bands was prescribed according to the fitness level of the participants. The exercises were performed in sets of 10 to 15 repetitions, and the participants performed 2 to 3 sets depending on their physical condition of the day. The number of days the resistance training could be performed in 12 weeks was recorded.

We recorded the number of days the supine ergometer exercise was implemented during the A period, and that for both the resistance training and supine ergometer exercises during the B period. Additionally, the driving distance of the supine ergometer during the A and B periods was recorded each time, and the average driving distance and total driving distance during the A and B periods were calculated.

Five participants withdrew during the B period, and 18 participants (16 males and 2 females, age 61 ± 12 years) completed this study. Three of the participants had a prolonged B period due to restrictions caused by coronavirus infection. However, since studies of patients undergoing hemodialysis often set up suspension periods and account for dropouts, we examined the effect of including the suspension period in this study in the intention-to-treat analysis.

All measurements in this study were shown as mean and standard deviation. The physical function data obtained during the three measurement time points were compared using the repeated measure analysis of variance. Associations between measurements were determined using the Pearson correlation coefficient. To determine the impact of additional combined interventions on 6MD, multiple regression analysis was performed using the 6MD result after the B period as the dependent variable. The independent variables were the exercise record data during the intervention period, such as the number of days of the resistance training, the number of days of supine ergometer exercise, the average driving distance of supine ergometer, total driving distance of supine ergometer, and Borg scale, to examine the relationship with the exercise component during the intervention. All statistical analyses were performed using SPSS version 25.0 software (IBM, Armonk, NY, USA). Statistical significance was set at 5%.

RESULTS

The physical functions are shown in Table 1. The 6MD result improved significantly after the additional combined intervention compared to before the additional combined intervention ($p<0.05$). The exercise recorded data are shown in Table 2. There was no significant difference in the exercise records of the supine ergometer before and after the additional combined intervention.

Table 1. Changes in physical function over time

	First round (n=18)	Second round (n=18)	Third round (n=18)
Grip strength (kg)	31.51 ± 7.88	32.31 ± 8.08	33.07 ± 7.40
Knee extension muscle strength (kg/m)	1.13 ± 0.45	1.26 ± 0.54	1.24 ± 0.42
One-leg standing time (s)	41.89 ± 24.01	40.62 ± 24.09	38.72 ± 25.20
TUG (s)	5.87 ± 1.68	5.81 ± 1.63	5.89 ± 1.42
6MD (m)	516.29 ± 115.60	504.35 ± 167.48	534.76 ± 160.44*

Comparison of the results of the repeated measures analysis of variance among the three rounds. Comparison between the second and third round data: *p<0.05. TUG: timed up & go test; 6MD: 6-min walk distance test.

Table 2. Record of intervention

Items		A period (n=18)	B period (n=18)
Resistance training	Number of days of resistance training (day)	Not implemented	28.33 ± 11.00
Supine ergometer exercise	Average driving distance (km)	1.98 ± 0.43	1.91 ± 0.44
	Total driving distance (km)	64.26 ± 23.31	63.06 ± 23.63
	The number of days of supine ergometer exercise (day)	32.78 ± 9.01	32.50 ± 8.21
	Borg scale (respiratory fatigue)	10.29 ± 1.98	10.47 ± 2.23
	Borg scale (lower limb fatigue)	10.61 ± 2.15	10.84 ± 2.44

Significant correlations were found between the 6MD results after the additional combined intervention and grip strength, knee extensor strength, one-leg stance, TUG result, and average driving distance after the additional combined intervention (Table 3). To examine the effect of the exercise intervention on the 6MD, multiple regression analysis was conducted with the 6MD result after the additional combined intervention as the dependent variable and the record of the exercise during the additional combined intervention period as the independent variable (Table 4). As a result, only the average driving distance was adopted as the independent variable. This multiple regression equation had an R of 0.609 and an R^2 of 0.371.

DISCUSSION

In the present study, the 6MD result improved significantly after the additional combined intervention (Table 1). On the other hand, while there was no difference in the records of supine ergometer exercise performed before and after the additional combined intervention (Table 2). It was suggested that even patients who maintained their physical function with only supine ergometer exercises during dialysis could improve their walking endurance with the addition of resistance training later on. The 6MD has been implicated in the survival of patients undergoing hemodialysis, with a reported increased life expectancy of approximately 5.3% for every 100 m walked[11)]. Although the overall improvement in this study was approximately 30 m, some participants showed an improvement of >100 m, which may have had a positive effect on survival.

In the current study, the number of resistance exercises and supine ergometer exercises, total distance traveled during the intervention period, average driving distance, and subjective exercise intensity during supine ergometer exercises were recorded during the additional combined intervention period. Among those variables, only the average driving distance was correlated with the 6MD result after the additional combined intervention. Since the average driving distance of a supine ergometer exercise did not change between the A and B periods, the improvement in 6MD after the B period could be attributed to the addition of resistance training. However, it was suggested that it is the driving distance of daily supine ergometer that has a direct effect on 6MD. A meta-analysis examining the effects of exercise on dialysis patients showed that aerobic exercise prolonged the distance of the 6-minute walk, but resistance training had no effect on the 6-minute walk distance[12)]. An RCT intervention combining aerobic exercise and resistance training has shown an increase in the 6-minute walking distance[13)]. If the results of the present study are taken into account, even if there is no change in physical function with the supine ergometer exercise, resistance training alone is unlikely to be effective, and it is important to use additional resistance training in combination. In this case, maintaining the driving distance of the supine ergometer exercise may affect the improvement of 6MD.

The limitation of this study was that there were very few participants. While we found significant results through this pilot study, it is necessary to collect more participants in the future to verify the cutoff value. In addition, the present study could not adjust for dialysis history or age group. By increasing the number of participants in the future, it will be possible to stratify the data according to age, dialysis history, and primary diseases. Another issue was that some patients were suspended from the study due to infectious diseases. It is necessary to consider the contents of the exercise program and how to motivate participants to exercise to prevent them from stopping or dropping out in the future.

Our exercise program was associated with improved 6MD results, which suggests improvement in walking endurance by the intervention of the additional combined use of resistance training before dialysis in supine ergometer exercise during dialysis. The average driving distance of the daily ergometer during the intervention period was associated with the 6MD result after the intervention. When resistance exercise is additionally used in combination, it is important to maintain the average driving distance of the supine ergometer exercise. It was suggested that the improvement of gait endurance by the

Table 3. Correlation coefficient of data

	Grip strength	Knee extension muscle strength	One-leg standing time	TUG	Average driving distance
6MD	0.613**	0.784**	0.613**	−0.809**	0.609**

Physical function data was taken from Third round data. **p<0.01. TUG: timed up & go test; 6MD: 6-min walk distance test.

Table 4. Results of multiple regression analysis with 6MD after the B period result as the dependent variable and exercise record data during the B period as the independent variable

Adopted independent variable	β	Partial correlation coefficient	Variance inflation factor	p-value
Average driving distance	0.609	0.609	1.000	<0.01

R=0.609, R^2=0.371.
The variables were selected by a stepwise method.
The excluded variables are as follows: total driving distance, number of days of resistance training, number of days of supine ergometer exercise, Borg scale score for respiratory fatigue, and Borg scale score for lower limb fatigue.
6MD: 6-min walk distance test.

addition of resistance training could be achieved by ensuring a certain amount of aerobic exercise. These results will help in the future prescription of exercise for patients on dialysis.

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Conflicts of interest

The authors declare that they have no competing interests.

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