Aerobic training during hemodialysis improves body composition, muscle function, physical performance, and quality of life in chronic kidney disease patients

YOUNG-HYEON BAE, PT, PhD1,2), SUK MIN LEE, PT, PhD3)*, JONG IL JO, PT, DPT4)

1) Department of Physical and Rehabilitation Medicine, Samsung Medical Center, Republic of Korea
2) Department of Physical Therapy, Angelo State University, USA
3) Department of Physical Therapy, Sahmyook University: 26-21 Gongneung2-dong, Nowon-gu, Seoul, Republic of Korea
4) Department of Physical Therapy, New York University, USA

Abstract. [Purpose] We assessed the influences of individualized aerobic training on body composition, knee joint muscle function, physical performance, and quality of life in chronic kidney disease patients. [Subjects] Ten chronic kidney disease patients undergoing dialysis. [Methods] Overall physical function and quality of life before and after 12 weeks of aerobic training were evaluated by body composition, the six-minute walk test, cardiovascular exercise tests, and Short Form 36-item questionnaire. [Results] The six-minute walk test distance increased significantly after 12 weeks aerobic training. Resting metabolic rate, lactate threshold, maximum oxygen uptake, and quality of life tended to increase after training. Post-training weight, muscle mass, body fat mass, fat percentage, body mass index, and peak torque of right and left knee extension and flexion did not change significantly. [Conclusion] Intra-dialytic training can a safe approach to maintain or improve physical performance and quality of life of chronic kidney disease patients undergoing hemodialysis without adverse events or negative cardiovascular responses. Aerobic training may prevent a decline in body composition and knee joint muscle function due to inactivity in chronic kidney disease patients. Clinically, aerobic training may initially be adapted to maintain overall physical function or improve quality of life in chronic kidney disease patients undergoing hemodialysis.

Key words: Aerobic training, Physical performance, Hemodialysis

INTRODUCTION

Chronic kidney disease (CKD) is a severe health-related problem1). More than one million of necessitate hemodialysis (HD) and renal transplantation all over the world for the year2). As renal function deteriorates, finally get to the life-threatening end stage3–5). The usual consequences of uremic syndrome include decreased physical ability (by approximately 50%), diminished quality of life (QOL), and increased cardiovascular disease6–8). Dialysis interventions are generally performed three times per week for 4–6 hours per session. This causes HD patients to have a monotonous and restricted daily life, limiting their activities after treatment onset as well as contributing to and supporting sedentary habits, functional disability, and inactivity9). Activity limitations are often caused by muscle atrophy, which affects 18–80% of patients undergoing dialysis10–13). Muscle wasting is another remarkable problem and is a significant anticipator of morbidity and mortality14). Muscle quantity is strongly correlated with muscle strength, muscle oxygen extraction, and functional ability in HD patients10,11,15,16). In rare cases, the quadriceps tendon and patellar ligament are susceptible to rupture17).

Establishing a physical activity routine for patients on dialysis has advantages such as greater willingness to engage in training, convenient scheduling, reduced boredom of dialysis sessions, and better ease of medical care. In addition, physical activity in HD patients is related with improved physical capacity and reduced blood pressure, and also contributes to improved QOL18,19). However, the physical condition of HD patients limits their ability to perform high-intensity training such as resistance training20). Recent investigations have promoted intra-dialytic training as a beneficial intervention to enhance compliance, improve motivation, and promote the medical monitoring3,19). The majority of training programs are performed between dialysis sessions. Therefore, this study assessed the impacts of individualized aerobic training programs supervised and carried out during dialysis sessions on body composition, muscle function of the knee joint, physical performance, and QOL in HD patients.
SUBJECTS AND METHODS

Ten CKD patients who were undergoing maintenance dialysis in the outpatient HD unit were enrolled. The institutional review board approved all procedures. They were evaluated for eligibility based on review of medical history and physical examination. The inclusion criteria contains: older patient; during dialysis for more than three months; approval from physician; independent ambulation for at least 50 m, and properly dialyzed and stable during dialysis.

A single-group interventional study design was used to confirm the influence of aerobic training in HD patients. Body composition, muscle function of the knee joint, physical performance, and QOL were evaluated. After these assessments, the patients underwent supervised exercise capacity during dialysis sessions for 12 weeks. These variables were re-assessed in the post-training phase.

Training consisted of a warm-up, aerobic training on a stationary bicycle, and a cool-down. For the warm-up, patients performed passive stretching of the lower limbs and aerobic activity on the bicycle at 0.5 km/h (approximately 35 rpm), which is the lowest load applicable to the ergometer (700r recumbent bike, Cybex, Boston, USA) used, for 5 minutes. After the warm-up, the conditioning phase included 30 minutes of training during the first two hours of dialysis to avoid physical stress in the second half of the session when patients’ hemodynamic conditions are unfavorable. Heart rate was constantly monitored using a heart rate monitor (H1 heart rate sensor, Polar, NY, USA), and blood pressure was measured at rest every five minutes during training and after the cool-down period. The cool-down consisted of two minutes on the bicycle with minimal load at 35 rpm followed by passive stretching of the lower extremity.

The prescribed training intensity was based on Borg’s Perceived Exertion Scale. According to this scale, patients assign a score to the intensity of fatigue ranging from 6–20 points. Every 5 minutes during the aerobic training, patients were asked about the score they would assign to their fatigue at that moment, and the bicycle load was adjusted to achieve sufficient intensity to maintain a fatigue score between 11 and 13 points, which corresponds to an intensity of “mild” to “quite hard.” The rotation speed of the pedals remained close to 35 rpm to achieve stable training intensity.

The Inbody 720 (Biospace, Seoul, Korea) was used to confirm body composition calculated from weight, mass of skeletal mass, mass of body fat, percentage of body fat, and body mass index which was measured by the electrical resistance to four frequencies in each body part. The electrical resistance was measured body composition by attaching sensors on the patient in standing position.

Maximum peak torque in the knee joint was assessed using the isokinetic digital cybex system (HUMAC NORM, NY, USA); this is a noninvasive method that uses the isokinetic mode and enables reliable measurement. Both lower limbs were tested. The patient was instructed on how to perform the task each time. The test relies on flexion and extension of the legs at the knee joint with maximum force and measures maximum flexion and extension peak torque at an arc speed of 60°/s (five movements with a one-minute rest between each set).

Training testing was performed using a branching treadmill protocol with modified Bruce that started at a brisk walking speed; speed increased gradually every two minutes to assure that at least four measurements were obtained between rest and peak training. Patients were instructed to exert themselves to maximum levels. When the patient was unable to keep pace with the treadmill or requested to stop, cardiac output was measured before stopping. The electrocardiogram was measured constantly for oxygen uptake (VO2 in L/min), and cardiac output were estimated at each stage. All tests were conduct on the same day in the same order. HD patient performed the evaluations on inter-dialytic days.

The six-minute walk test (6MWT) was used as an index of physical endurance and was conducted before and after training. The 6MWT is reliable for establishing the physical capacity of patients with heart and respiratory insufficiency as well as patients with chronic renal failure. This test can be used to assess the influence of rehabilitation, particularly for subjects in whom maximal training testing is not possible, such as elderly patients. The 6MWT was performed on the day of dialysis before the HD session. Patients walked unassisted for 25 m down the hospital corridor accompanied by a physiotherapist; they were permitted to stop to rest. The distance (m) was recorded for each patient.

To evaluate QOL, the SF 36-item questionnaire was used. This questionnaire has 36 items divided into eight divisions: physical function, role of physical, body pain, general health, vitality, social function, role of emotional, and mental health. Each scale is graded from 0–100. Higher grades indicate better self-perception of QOL.

The Shapiro-Wilk test was verified normality distribution of data. After verifying that the data were normally distributed, all the analyses were conducted using parametric tests. Paired t test was used to compare the values between before and after training. It was considered significantly difference when the p value was < 0.05 using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Mean age was 56.50 ± 4.48 years (males: 55.50 ± 7.96, females: 57.17 ± 5.88), and mean height was 158.08 ± 2.72 years (males: 167.23 ± 1.74, females: 151.98 ± 1.53).

There were four males (40%) and six (60%) females. The number of complications ranged from one to five (Table 1).

The goal of 30 minutes of tolerance to training was achieved around the fourth week. It is worth noting that no clinical complications occurred during training; there was only one episode of absence without leave, and training was resumed at the next dialysis session.

There were no difference between before and after training in weight, muscle mass, body fat mass, fat percentage, body mass index, and peak torque of knee extension and flexion. Each post-training variable (97.4% to 103.0%) was quite similar to pre-training values (Table 2).

The average pre-training distance traveled in the 6MWT was 390.80 ± 78.62 m, compared to a post-aerobic training value of 419.00 ± 93.68 m. Thus, the distance traveled after the aerobic training increased significantly (p < 0.05). There
were no significant changes in resting metabolic rate, lactate threshold, VO\textsubscript{2}\text{max}, or QOL subscale scores. However, each of these variables increased after training (Table 3).

**DISCUSSION**

There are no known data concerning physical fitness and training tendency in Korean HD patients, but similar data from other countries including the U.S. have showed 45% of dialysis patients seldom training, and only 8% of patients among entirety HD patients did training at least once a week \(^6\).

In this study, we observed that aerobic training sessions held during dialysis were associated with or maintained or increased physical performance, QOL, control of body composition and muscle function of the knee joint, and increased safe participation in physical activity.

Muscle wasting is common in HD patients and concerns with rose morbidity and mortality \(^{22}\). Muscle wasting is caused by a variety of reasons and process begins early in the disease \(^{23, \ 24}\). The resistance training of high-intensity was to improve the muscle strength of HD patients \(^{25, \ 26}\). Similar trials \(^{27, \ 28}\) showed to improve muscle strength by regimens with lower-intensity strength training. Resistance training highly increases metabolism of protein synthesis, leading to increased cross-sectional volume of muscle fibers. In contrast, another study was no changes of lower extremity strength following six weeks of dialysis period \(^{29}\). However, this is not unpredictable considering that aerobic training is not the preferred intervention for improving muscle strength \(^6\). In comparison, aerobic training leads to the depletion of free intramuscular amino acids. While aerobic training alone is not enough to activate hypertrophy, it can maintain skeletal muscle mass \(^{29}\). In the our study,

| Table 1. General characteristics in the subjects |
|-----------------------------------------------|
| Age (years) | Gender        | Height (cm) | Complications                      |
| 1           | 42            | Male        | 167.6                              | diabetes, hypertension, anemia |
| 2           | 42            | Male        | 162.7                              | diabetes, hyperlipidemia, anemia, autoimmune disease |
| 3           | 62            | Female      | 156.7                              | hypertension, arthritis, anemia, autoimmune disease |
| 4           | 73            | Male        | 167.4                              | diabetes, hypertension, anemia |
| 5           | 47            | Female      | 154.3                              | hyper-tension, anemia           |
| 6           | 34            | Female      | 154.3                              | diabetes, hypertension, anemia, autoimmune disease, tuberculosis |
| 7           | 62            | Female      | 146.6                              | diabetes                          |
| 8           | 65            | Male        | 171.2                              | diabetes, hypertension, anemia, autoimmune disease, spinal stenosis |
| 9           | 63            | Female      | 149.9                              | diabetes, hypertension, arthritis, anemia,                        |
| 10          | 75            | Female      | 150.1                              | hypertension, arthritis          |

| Table 2. Pre- and post-training on body composition and knee joint muscle function |
|-----------------------------------------------|
| Variable                                         | Pre-training          | Post-training         |
| Body composition                                  |                         |                         |
| Weight (kg)                                      | 59.6±11.8              | 59.8±11.4              |
| Muscle mass (kg)                                 | 22.7±4.4               | 22.5±4.1               |
| Body fat mass (kg)                               | 17.2±7.0               | 17.7±6.8               |
| Fat percentage (%)                               | 28.2±6.8               | 29.0±7.1               |
| Body mass index (%)                              | 23.9±4.5               | 23.8±4.5               |
| Muscle function of knee joint                    |                         |                         |
| Right knee extension (peak torque)               | 50.4±25.3              | 51.9±24.2              |
| Right knee flexion (peak torque)                 | 23.5±13.3              | 26.0±11.8              |
| Left knee extension (peak torque)                | 45.7±26.4              | 44.5±24.4              |
| Left knee flexion (peak torque)                  | 23.6±15.7              | 23.1±12.9              |

No significant difference between pre- and post-training

| Table 3. Pre-and post-training on physical performance and QOL |
|-----------------------------------------------|
| Variable                                         | Pre-training          | Post-training         |
| 6MWT (m)                                         | 390.8±78.6            | 419.0±93.7            |
| RMR (kcal/day)                                   | 895.2±272.4           | 977.8±396.7           |
| LT (mL/min)                                      | 703.8±450.6           | 738.2±421.5           |
| VO\textsubscript{2}\text{max} (mL/min)            | 965.0±439.8           | 993.2±385.7           |
| QOL (score)                                      | 1,392.0±494.2         | 1,596.9±647.8         |

*p < 0.05, 6MWT: six-minute walk test, RMR: resting metabolic rate, LT: lactate threshold, VO\textsubscript{2}\text{max}: maximum oxygen uptake QOL: quality of life
there were no significant change on body composition and muscle function of the knee joint. However, each of these variables was quite similar between before and after-training (97.4–103.0% of the respective pre-training values).

This study used the 6MWT, because it is most commonly used test to estimate physical performance, is easy to use, inexpensive, and is representative of daily activities. This test is widely used in patients with cardiac and lung diseases, but its application in HD patients in clinical research is often limited. The average distance achieved in the 6MWT in the pre-training phase was comparable to that achieved in other studies evaluating HD patients. After aerobic training, the distance covered in the 6MWT increased significantly indicating considerable improvement in physical endurance. These findings were coherent with previous study observed an improve of physical performance in patients undergoing dialysis according to the 6MWT after 20 weeks of training.

In our study, there were no significant changes on resting metabolic rate, lactate threshold, VO2max, or QOL, although each of these variables tended to increase after training. HD patients was can significantly increase their VO2max 17–23% by performing aerobic training during dialysis. In contrast, a little studies reported no significantly changes of VO2max following aerobic training, for that reason attributed to prescribing low intensity or short duration aerobic training. Several studies of training in HD patients have used SF36 scores as a measurement of QOL. Improved QOL have been presented after aerobic training of 3–5 months. These findings suggest the benefit of a supervised training program for improvement of physical performance and QOL.

People who persistently have a sedentary lifestyle have a greater risk of adverse cardiac events than those who progressively improve their physical activity level. In comparison with risks associated with vigorous activities, risk of accidental heart problem in light to moderate intensity activities is lower. Thus, training according to these recommendations incur a lower cardiovascular risk than vigorous training. As required training test before starting a low-intensity physical activity program would constitute a substantial barrier to participation for many patients and could consequently contribute to an increased risk of remaining sedentary. Pre-training testing is unnecessary, because the recommendations are for gradually increasing low-intensity activity and because the recommendations are made according to the individual’s ability with regard to chronic conditions and lower energy levels. In our study, patients were willing to participate in 95% of the training sessions, and the goal of 30 minutes of tolerance to training was achieved by patients around the fourth week. No relevant clinical complications occurred during training; there was only one instance of absence without leave, with a resumption of training at the next dialysis session.

In summary, aerobic training during dialysis sessions is a safe and tends to be associated with improvements in physical performance and QOL. It also contributes to the maintenance of body composition and muscle function of the knee joint in HD patients. Therefore, aerobic training can increase participation in physical activity and appears to be a safe approach to initiating training. Further research is required to resolve the composition of interventions including type, duration, intensity, frequency and these data will require confirmation in samples with a larger number of patients.

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