J Prev Epidemiol. 2020;5(2):e21 Original Article

doi 10.34172/jpe.2020.21 Journal of Preventive Epidemiology http jprevepi.com

Evaluating the effect of intradialytic exercise on blood pressure, inflammatory markers and dialysis adequacy

Parvin Soltani[1], Naser Saeedi[1*], Navidreza Mashaykhi[2], Alireza Rostami[3], Maryam Tajfar[1]

[1]Department of Internal Medicine, Faculty of Medicine, Arak University of Medical Sciences, Arak, Iran
[2]Department of Cardiology, Faculty of Medicine, Arak University of Medical Sciences, Arak, Iran
[3]Department of Cardiac Surgery, Faculty of Medicine, Arak University of Medical Science, Arak, Iran

Correspondence to:
Naser Saeedi, Email: DR.N.Saeedi@arakmu.ir

Received: 20 August 2020
Accepted: 10 Oct. 2020
ePublished: 29 Oct. 2020

Keywords: Dialysis quality, Hypertension, Inflammatory mediator CRP, Intradialytic exercise, End-stage renal disease, Chronic kidney failure, Hemodialysis

Abstract

Introduction: In spite of widely accepted idea that exercise is beneficial in dialysis, it is not easy to incorporate an exercise program into routine clinical practice of these patients.
Objectives: The present study was conducted to evaluate the effects of exercise on hemodialysis patients.
Patients and Methods: In this non-pharmacologic clinical trial, a total of 49 clinically stable hemodialysis patients were enrolled in the study and were randomly allocated into two groups; the intervention group (n=27) and the control group (n=22). The intervention group conducted at least 30 minutes of cycling during each hemodialysis session for six months. Intradialytic blood pressure, high-sensitivity C-reactive protein (hs-CRP) blood levels and dialysis adequacy were estimated before and after dialysis.
Results: At the end of the 6-month study period, a significant reduction in systolic and diastolic blood pressure in all patients of the intervention group ($P<0.05$) was detected. Although the dialysis quality increased more than 1.2, it was not statistically significant. Moreover hs-CRP was decreased in the exercise group at the end of the study, while these outcomes were not statistically significant too.
Conclusion: Intradialytic exercise can lead to a significant reduction in systolic and diastolic blood pressure in hemodialysis patients.
Trial registration: This randomized controlled trial was registered in the Iranian Registry of Clinical Trials (#IRCT2015092324152N1, https://irct.ir/trial/20465, ethical code; ARAKMU.REC.1393.168.1).

Citation: Soltani P, Saeedi N, Mashaykhi NR, , Rostami AR, Tajfar M. Evaluating the effect of intradialytic exercise on blood pressure, inflammatory markers and dialysis adequacy. J Prev Epidemiol. 2020;5(2):e21. doi: 10.34172/jpe.2020.21.

Introduction

Chronic kidney failure is considered as one of the important public health issues which are increasing in most communities (1). Over 50 million people around the world have chronic kidney failure and more than one million people need alternative interventions such as dialysis and kidney transplant. In recent years, rise of hypertension and diabetes has led to increased prevalence of chronic kidney failure (2). End-stage renal disease (ESRD) is a stage in which 90% of kidney function has lost and the body cannot maintain the balance of fluids, electrolytes and normal hormonal function since kidney cannot clear all waste material (3). There are several alternative methods for replacing renal function. Hemodialysis is the most common method among them. Nowadays, more than two million people undergo hemodialysis around the world (4,5). Dialysis is a time-consuming method and should be done at least 2 or 3 times per week and each time for four hours (6). Despite the fact that dialysis can improve some lost functions of the kidney, dialysis patients still suffer from some symptoms such as uremic syndrome. Its symptoms include autonomic and motor neuropathy, heart and skeletal muscle myopathy, disruption of bone metabolism, changes in peripheral vessels, anemia, losing immune system function and some other symptoms such as nausea, vomiting, insomnia and fatigue (3). High-quality dialysis can improve life quality and increase the longevity of dialysis patients (7).

Changing lifestyle in order to increase physical activity reduces mortality rate in the

Key point

In a non-pharmacologic clinical trial, on 49 clinically stable hemodialysis patients who were randomly allocated into two groups of intervention group (at least 30 minutes of cycling during each hemodialysis session for six months) and the control group, we found a significant reduction in systolic and diastolic blood pressure in the patients of the intervention group. Moreover hs-CRP was decreased in the exercise group at the end of the study, while this outcome was not statistically significant too.

general population (8).

Available guidelines suggest that healthy people should have moderate physical activity in most of the days (9). A high rate of mortality was reported in ESRD patients who undergo dialysis. It might be a greater positive effect from physical activity in these patients compared to the general population. In addition to reduction of cardiovascular risk, exercise can improve physical performance and subsequently the quality of life among patients (10). It has been shown that intradialytic exercises have positive effects on the amount of phosphorous, potassium and anemia and leading to the effectiveness of dialysis and improved urea clearance (11,12).

Although exercise programs often have been among hemodialysis sessions, recent studies focus on intradialytic exercise to improve patients' lives (3). Exercise is often conducted during the first minutes of dialysis because the cardiovascular response is more stable in this phase (13). Reducing activity can be due to several reasons such as anemia, reduction of blood supply in organs, disruption of heart function and declined daily activities in the dialysis patients (14). It should be mentioned that hemodialysis patients are not excluded from the positive effects of exercise on the general population. The positive effects of exercise on reducing chronic diseases have been shown in various studies (15). However, the effect of exercise especially intra-dialysis exercise on hemodynamic control, dialysis quality and comprehensive guide related to the type of exercise and also its appropriate time needs more research and study among the hemodialysis patients.

Objectives

Given that hemodialysis patients are considered as disabled people and undergo numerous mental and physical impairments, therefore any attempt for improvement of their life quality and institutionalization of exercise in this group of patients seems to be beneficial and necessary. Therefore, the present study was conducted to evaluate the effects of exercise on these patients.

Patients and Methods

Study design and setting

In this non-pharmacologic clinical practice study, 49 hemodialysis patients which referring to Valieasr hospital were enrolled in the study. Selected patients were randomly assigned in intervention (experimental) and control group. In this study, protocol of research and intervention was explained to patients. They completed informed consent and were informed that they can be excluded from the study whenever they decided.

In the intervention group, fixed bike was placed next to the patient's bed and exercise severity was designed based on previous activities. It was first evaluated how long the patient can tolerate activity. Most of the patients could tolerate a few minutes of light activity. This minimum time was used to start exercise then each 2-3-minute session (based on patient's tolerance) was added to cycling time until obtaining maximum of 30 minutes.

When cycling duration reaches 15 minutes, cycling was conducted at 12-16 rate of perceived exertion (RPE) for maximum of 30 minutes along with 10 minutes warm up. Warm up and cool down phase were conducted at 9-10 RPE and the main phase was done at 12- 16 RPE (16).

Thirty minutes *sit-to-stand* test was used to evaluate muscle strength of the patient. The test was conducted at the first session before exercise program, 12th and 24th week. The test was conducted as follows: a chair with a solid seat area and height of 40-50 cm was used and the subject was asked to sit and stand in 30 seconds. The number of sit and stand of the patient was recorded at the fastest rate without the help of hands and at the end of 30 seconds (17,18).

The exercise program includes aerobic which was simultaneously conducted with dialysis session three times a week. Additionally 6-minute walk test (6 MWT) was applied to evaluate the performance capacity of patients. It was performed at the beginning of the design (baseline), in 12th and 24th weeks, based on the suggested process by the American thoracic society. The patient was asked to walk 25 m distance in the dialysis section for six minutes. The beginning and end of the distance were determined. If the patient became tired they can stop sitting. After that, the patient should continue walking. The timer was not stopped, if the patient stops walking and the time was recorded at the end of 6 minutes. The test should be stopped, if the heart rate is more than 120 in minutes at rest or systolic blood pressure is greater than 180 mm Hg or diastolic blood pressure is greater than 100 mm Hg (19,20). Blood pressure and heart rate of the patient were measured at the beginning of the exercise, in the 15th and 30th minutes and at the end of dialysis. Besides, the exercise will stop if the patients experience hypotension or tachycardia or other similar symptoms. Whether there is a history of unstable angina or myocardial infraction during last month, the test stopped.

Dialysis quality of the patient was determined by estimating Kt/V and URR as follow:

$$Kt/V = 0.04(co\text{-}ct/co)\ (100) - 1.2k$$

In this formula, k represents urea clearance of the given filter, T represents the duration of the dialysis, V represents distribution volume of urea or volume distribution of water, Co and Ct represent blood urea before and after dialysis, respectively, which were finally expressed by mmol/L (8,21,22). The value of C-reactive protein (CRP) was measured before and 6 months after in both groups. Serum CRP was measured by high sensitive quantitative method.

Ethical issues

The research followed the tenets of the Declaration of

Helsinki. Informed consent was obtained from all patients. The study was approved by the ethical committee of Arak University of Medical Sciences (ethical code; ARAKMU.REC.1393.168.1). This paper is a part of thesis of Maryam Tajfar in the department of internal medicine of the Arak University of Medical Sciences. Besides that, the study protocol was registered as in the Iranian registry of clinical trials (#IRCT2015092324152N1, https://irct.ir/trial/20465). This research was supported by Arak University of Medical Sciences (Grant# 5004).

Statistical analysis

Complete stages of exercise were described in the intervention group (exercise group) before entering the study. It was a 6-month exercise program and was done under the supervision of sports medicine specialist, physiotherapist, nephrologists and nurse. The exercise was complete three times a week according to the dialysis program and in the first 2 hours. The exercise program was cycling on a fixed bike. Technogym fixed bike, Model Excite with work out adjustment and applied fixed load range (light–hard) was used.

Results

In this clinical trial, the total samples are 49 subjects in the intervention (N = 27) and the control group (N = 22), while male to female ratio is the same in both group (chi-square test; $P<0.05$). There is no significant difference among average age, duration of kidney failure and hemodialysis duration in both group (independent *t* test; $P\geq0.05$).

There is no significant statistically different among urea, blood urea nitrogen (BUN), CRP, dialysis quality, systolic and diastolic blood pressure in both groups at the beginning of the study based on Table 1 (independent *t* test; $P\geq0.05$).

Accordingly, Table 2 shows the comparison of data of both groups six months after the intervention (paired *t* test).

Table 3 shows the mean (standard deviation) of CRP before and after the intervention in both groups. While the mean of CRP was decreased in the intervention group, the results of paired *t* test showed that CRP levels have no significant difference before and after the exercise in two groups.

Table 4 shows the mean and standard deviation of dialysis quality (Kt/V) before and after the intervention in both groups. In the intervention group, the mean of Kt/V was increased, however the results of paired *t* test showed that the mean of Kt/V before and after the exercise has no statistically significant difference in both groups.

Figure 1 shows a significant reduction during six months of exercise intervention (repeated observations analysis with 4 weeks frequency).

Based on Figure 2, the mean of diastolic blood pressure had a significant reduction during six months of exercise intervention (repeated observations analysis with 4-week frequency).

Discussion

Patients who require dialysis are considered as disabled individuals in the community and are exposed to numerous mental and physical impairments; therefore any effort for improving their quality of life is useful and necessary. Previous studies stated the beneficial effect of

Table 1. The comparison of data of both groups at the beginning of the study

Variable/group	Urea (mg/dL)	CRP(mg/L)	Systolic pressure (mm Hg)	Diastolic pressure (mm Hg)	Dialysis adequacy
Intervention	111.09± 28.9	0.93±0.67	142±20.2	81.2±5.9	0.91±0.6
Control	108.77±48.4	1.08±0.72	127±22.3	78±3.4	1.04±0.7
P	0.692	0.486	0.591	0.395	0.341

Table 2. The comparison of the kidney indices average after the study of two groups

Group	Urea (mg/dl)		*P* value[a]
	Before	After	
Intervention	111.09± 28.9	81.2±35.4	0.671
Control	108.77±48.4	77.24±26.8	

[a] *t* test.

Table 3. The mean and standard deviation of CRP before and after the exercise in both groups

	CRP (mg/L)				Paired *t* test		
	Before		After				
	Mean	SD	Mean	SD	Degree of freedom	T	Significance level
Control	1.08	0.72	1.13	0.6	23	-0.44	0.573
Intervention	0.93	0.67	0.90	0.6	23	0.183	0.573

Table 4. The mean and standard deviation of Kt/V before and after the intervention in both groups

	Kt/V				Paired *t* test		
	Before		After				
	Mean	SD	Mean	SD	Degree of freedom	T	Significance level
Control	0.8	0.3	0.7	0.2	47	1.57	0.450
Intervention	0.9	0.2	0.97	0.1	45	2.52	

exercise on these patients. Regarding their special physical condition and their disability, more studies are needed to determine detailed effects.

We studied the effect of the exercise on blood pressure, CRP (as a factor of inflammation) and dialysis efficacy. In our study, 49 dialysis subjects were studied [41 males (82%) and 9 females (18%)]. At the end of study, the mean of systolic and diastolic blood pressure showed a significant reduction in the intervention group, while the results of our study was agreed with the study by Cappy and colleagues (23).

Brent et al found that patients who had intra-dialytic exercise need anti-hypertensive medication less than previous one. Intervention group cycled during dialysis for six months. After three months, results showed a significant reduction in blood pressure before and after dialysis in the intervention group. Moreover, there was no significant difference between the two groups at the end of 6 months. This study showed that intradialytic exercise led to a reduction in taking anti-hypertensive drugs (24). In this study we measured diastolic and systolic blood pressure at least two times at each dialysis session. Hence, we had a total of 144 times blood pressure records which increased accuracy of this study. The results were monthly shown to simplify the statistical presentation.

Henrique et al showed that aerobic exercises during hemodialysis sessions help to improve physical capacity and control of hypertension in the subjects with chronic kidney failure as we observed in our study (25). The study by Orcy et al showed that diastolic blood pressure was significantly dropped in the exercise group at the end of 4th and 8th weeks (26). In addition, Paglialonga et al stated that intradialytic exercise is effective in performance capacity. Their findings showed that even a moderate intradialytic exercise (30 minutes two or three times a week) can have a positive effect on the physical fitness of these patients (27). Similarly, a significant reduction in diastolic blood pressure was also reported by Patrick et al. They concluded that aerobic activity can be effective in lowering blood pressure and slowing down the complications of kidney disease (28). Besides, McMurray et al showed that the mean of systolic blood pressure was decreased to 5.4 mm Hg which was statistically significant and suggested that, an hour exercise during dialysis can decrease blood pressure significantly (4). Although the above mentioned results are consistent with our results, no significant difference was detected in mean blood pressure of patients in the studies conducted by Salhab et al (29) and Parsons et al (30). Intra-dialytic exercise may be associated with a reduction in pulse pressure and improvement of cardiovascular system too. This may be due to the different type, intensity and duration of exercise in our study. Results showed that the mean of BUN before and after the intervention was not significantly different. Likewise, the mean of CRP decreased after the exercise however it was not statistically significant. Due to the growing trend of chronic kidney disease, the decrease in CRP will be beneficial in the CKD treatment. However it seems that six months is not enough to reach its best ameliorative effect.

The results of the study by Peres et al indicated that physical activity moderates the plasma levels of inflammatory factors (31). It should be mentioned that our study period was short.

At the beginning of our study, 43.2% of the samples

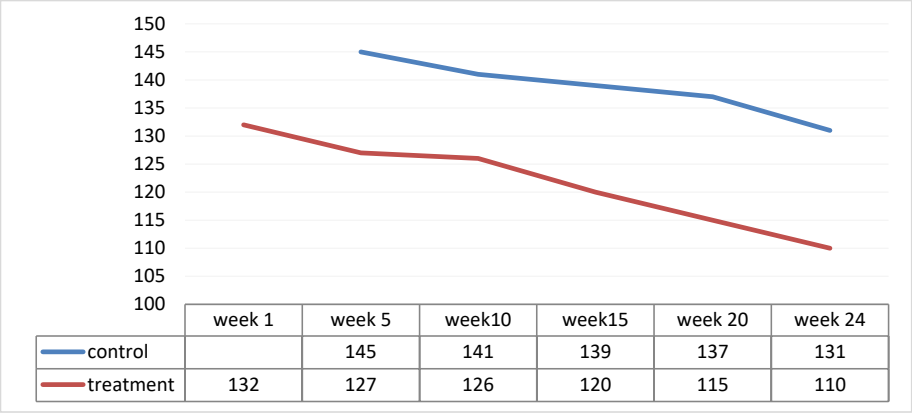
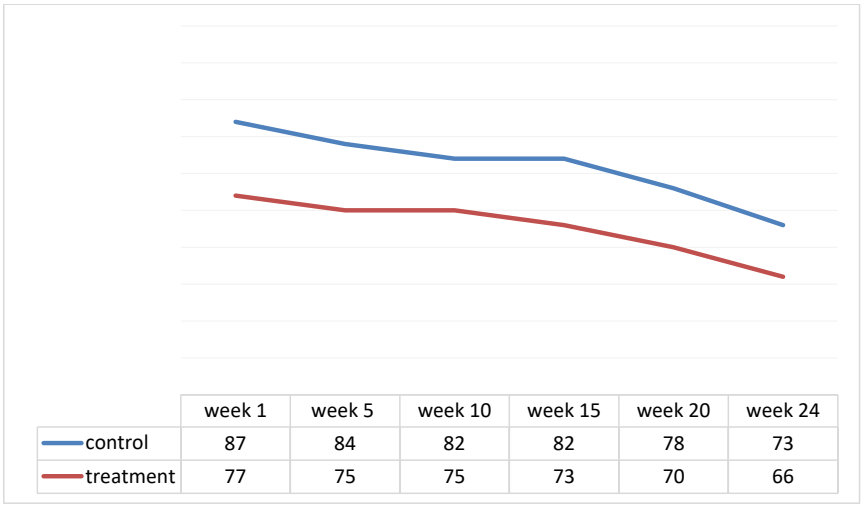


Figure 1. Comparison of the systolic blood pressure in two groups at a different times.



	week 1	week 5	week 10	week 15	week 20	week 24
control	87	84	82	82	78	73
treatment	77	75	75	73	70	66

Figure 2. Comparison of the diastolic blood pressure in two groups in different times.

had Kt/V less than 1.2, then at the end of 24th week, the Kt/V was increased from below 1.2 to more than or equal to 1.2 in 66.7% of the patients. This amount of increasing is important clinically, because according to Disease Outcome quality Initiatives (DOQI), minimum of recommended Kt/V for hemodialysis patients equals to 1.2 (32) and based on United State Renal Disease System (USRDS), the risk of mortality decreases by 7 percent for a 0.1 increase in Kt/V up to almost 1.2 (33). Using aerobic exercise during dialysis, Stavroula et al found a significant increase in urea reduction ratio (11%) and dialysis adequacy (38%) in the intervention group at the end of the 12th week. They stated that exercise causes a significant increase in dialysis adequacy (34). Nevertheless, there was no statistically significant increase in Kt/V.

In contrast, McMurray et al in a similar study showed the increased dialysis adequacy by 20% after two months of exercise however it was not statistically significant (4).

The Kt/V index improved 19.5% in the intervention group among females. Dialysis adequacy was higher in females than males in the study by Chiew et al (35) and Kugler et al (36). Chiew et al mentioned that this finding is due to the smaller body, less weight and urea distribution among females. The results of our study confirmed this claim. In contrast, Cheuk-ChunSzeto et al found no relationship between gender and dialysis adequacy (37).

Increased dialysis adequacy was not significant in both the control and intervention group which was in accord with the results of the study by Dashti et al studies (38). They stated that conducting regular intra-dialytic exercise results in increasing physical performance and reduces muscle atrophy, while it has no significant effect on dialysis quality (38).

Conclusion

Intradialytic exercise could have a clear and significant effect on reduction of diastolic and systolic blood pressure among dialysis patients. Further, the exercise increases kt/V and decreases CRP in patients. It is suggested that more studies are needed to prove the effectiveness of the exercise on dialysis quality and CRP in the patients.

Limitations of the study

This study is mainly limited by its relatively small sample size. Many caregivers were not willing to participate in this study because of cultural issues in Iran. It is also recommended that in future studies, variables such as quality of life, perceived social support and disturbances such as depression, stress and anxiety are considered among this group of caregivers. In the intervention group, regarding the reduction of drug type and blood pressure at the end of the plan the following findings are obtained by comparing before the exercise intervention and after the intervention: 3 patients stopped 100% taking the drug, 3 patients decreased 75% taking drug, 3 decreased 50%, 2 patients decreased 33% and 1 patient decreased 25% the type of drug. The number of participation sessions has a direct relationship with the reduction of the drug and blood pressure.

Authors' contribution

PS designed the study, observed accuracy and validity of the study. NS collected the data and follow the study. NM analyzed data. AR supervised the project. MT wrote the paper. All authors edited and revised the final manuscript.

Conflicts of interest

The authors declare that there is no conflict of interest.

Ethical considerations

Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

Funding/Support

This study was recorded from a research project which has simultaneously done with thesis with 93-168-1 code in Ethics

committee of Arak University of medical sciences. The researcher appreciated all hemodialysis patients who help the researcher to do study, dear colleagues at dialysis department of Vali-e Asr Medical Education Center of Arak city and research deputy of Arak University of Medical Sciences which help us in funding this research.

References

1. Mula-Abed WA, Al Rasadi K, Al-Riyami D. Estimated glomerular filtration rate (eGFR): a serum creatinine-based test for the detection of chronic kidney disease and its impact on clinical practice. Oman Med J. 2012;27:108-13. doi: 10.5001/omj.2012.23.
2. Zhang QL, Rothenbacher D. Prevalence of chronic kidney disease in population-based studies: systematic review. BMC Public Health. 2008;8:117. doi: 10.1186/1471-2458-8-117.
3. Parsons TL, Toffelmire EB, King-VanVlack CE. Exercise training during hemodialysis improves dialysis efficacy and physical performance. Arch Phys Med Rehabil. 2006;87:680-7. doi: 10.1016/j.apmr.2005.12.044.
4. McMurray A, Blazey L, Fetherston C. The effect of intradialytic foot pedal exercise on blood pressure phosphate removal efficiency and health related quality of life in haemodialysis patients. Ren Soc Aust J. 2008;4:38-44.
5. Magnard J, Deschamps T, Cornu C, Paris A, Hristea D. Effects of a six-month intradialytic physical ACTIvity program and adequate NUTritional support on protein-energy wasting, physical functioning and quality of life in chronic hemodialysis patients: ACTINUT study protocol for a randomised controlled trial. BMC Nephrol. 2013;14:259. doi: 10.1186/1471-2369-14-259.
6. Jung TD, Park SH. Intradialytic exercise programs for hemodialysis patients. Chonnam Med J. 2011;47:61-5. doi: 10.4068/cmj.2011.47.2.61.
7. Hauk M, Kuhlmann MK, Riegel W, Köhler H. In vivo effects of dialysate flow rate on Kt/V in maintenance hemodialysis patients. Am J Kidney Dis. 2000;35:105-11. doi: 10.1016/s0272-6386(00)70308-8.
8. Paffenbarger RS Jr, Hyde RT, Wing AL, Lee IM, Jung DL, Kampert JB. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. N Engl J Med. 1993;328:538-45. doi: 10.1056/nejm199302253280804.
9. U.S. Renal Data System. U.S. Renal Data System, USRDS 2008 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 2008
10. Johansen KL. Exercise in the end-stage renal disease population. J Am Soc Nephrol. 2007;18:1845-54. doi: 10.1681/asn.2007010009.
11. McGuire S, Horton EJ, Renshaw D, Jimenez A, Krishnan N, McGregor G. Hemodynamic instability during dialysis: the potential role of intradialytic exercise. Biomed Res Int. 2018;2018:8276912. doi: 10.1155/2018/8276912.
12. Daul AE, Schäfers RF, Daul K, Philipp T. Exercise during hemodialysis. Clin Nephrol. 2004;61 Suppl 1:S26-30.
13. Leung R. Physiological effects of exercise during dialysis on chronic renal failure. J Exerc Sci Fit. 2004;2:30-5.
14. Qiu Z, Zheng K, Zhang H, Feng J, Wang L, Zhou H. Physical exercise and patients with chronic renal failure: a meta-analysis. Biomed Res Int. 2017;2017:7191826. doi: 10.1155/2017/7191826.
15. Hambrecht R, Walther C, Möbius-Winkler S, Gielen S, Linke A, Conradi K, et al. Percutaneous coronary angioplasty compared with exercise training in patients with stable coronary artery disease: a randomized trial. Circulation. 2004;109:1371-8. doi: 10.1161/01.cir.0000121360.31954.1f.
16. Kavanagh T. Chronic heart failure. In: American Association of Cardiovascular & Pulmonary Rehabilitation. AACVPR Cardiac Rehabilitation Resource Manual: Promoting Health and Preventing Disease. Chicago, IL, USA: Human Kinetics; 2006. p. 141-7.
17. Bohannon RW. Reference values for the five-repetition sit-to-stand test: a descriptive meta-analysis of data from elders. Percept Mot Skills. 2006;103:215-22. doi: 10.2466/pms.103.1.215-222.
18. Buatois S, Miljkovic D, Manckoundia P, Gueguen R, Miget P, Vançon G, et al. Five times sit to stand test is a predictor of recurrent falls in healthy community-living subjects aged 65 and older. J Am Geriatr Soc. 2008;56:1575-7. doi: 10.1111/j.1532-5415.2008.01777.x.
19. Hernandes NA, Wouters EF, Meijer K, Annegarn J, Pitta F, Spruit MA. Reproducibility of 6-minute walking test in patients with COPD. Eur Respir J. 2011;38:261-7. doi: 10.1183/09031936.00142010.
20. Wise RA, Brown CD. Minimal clinically important differences in the six-minute walk test and the incremental shuttle walking test. COPD. 2005;2:125-9. doi: 10.1081/copd-200050527.
21. Smart N, McFarlane J, Cornelissen V. The effect of exercise therapy on physical function, biochemistry and dialysis adequacy in haemodialysis patients: a systematic review and meta-analysis. Open J Nephrol. 2013;3:25-36. doi: 10.4236/ojneph.2013.31005.
22. Painter P. Physical functioning in end-stage renal disease patients: update 2005. Hemodial Int. 2005;9:218-35. doi: 10.1111/j.1492-7535.2005.01136.x.
23. Cappy CS, Jablonka J, Schroeder ET. The effects of exercise during hemodialysis on physical performance and nutrition assessment. J Ren Nutr. 1999;9:63-70. doi: 10.1016/s1051-2276(99)90002-x.
24. Miller BW, Cress CL, Johnson ME, Nichols DH, Schnitzler MA. Exercise during hemodialysis decreases the use of antihypertensive medications. Am J Kidney Dis. 2002;39:828-33. doi: 10.1053/ajkd.2002.32004.
25. Henrique DM, Reboredo Mde M, Chaoubah A, Paula RB. [Aerobic exercise improves physical capacity in patients under chronic hemodialysis]. Arq Bras Cardiol. 2010;94:823-8. doi: 10.1590/s0066-782x2010005000043.
26. Orcy R, Antunes MF, Schiller T, Seus T, Böhlke M. Aerobic exercise increases phosphate removal during hemodialysis: a controlled trial. Hemodial Int. 2014;18:450-8. doi: 10.1111/hdi.12123.
27. Paglialonga F, Lopopolo A, Scarfia RV, Consolo S, Galli MA, Salera S, et al. Intradialytic cycling in children and young adults on chronic hemodialysis. Pediatr Nephrol. 2014;29:431-8. doi: 10.1007/s00467-013-2675-5.
28. Tucker PS, Scanlan AT, Dalbo VJ. High intensity interval training favourably affects angiotensinogen mRNA expression and markers of cardiorenal health in a rat model of early-stage chronic kidney disease. Biomed Res Int. 2015;2015:156584. doi: 10.1155/2015/156584.
29. Salhab N, Alrukhaimi M, Kooman J, Fiaccadori E, Aljubori H, Rizk R, et al. Effect of intradialytic exercise on hyperphosphatemia and malnutrition. Nutrients. 2019;11:2464. doi: 10.3390/nu11102464.
30. Parsons TL, Toffelmire EB, King-VanVlack CE. The effect of an exercise program during hemodialysis on dialysis efficacy, blood pressure and quality of life in end-stage renal disease (ESRD) patients. Clin Nephrol. 2004;61:261-74. doi: 10.5414/cnp61261.
31. Peres A, Perotto DL, Dorneles GP, Fuhro MI, Monteiro MB. Effects of intradialytic exercise on systemic cytokine in patients

with chronic kidney disease. Ren Fail. 2015:1-5.
32. Jindal KK, Manuel A, Goldstein MB. Percent reduction in blood urea concentration during hemodialysis (PRU). A simple and accurate method to estimate Kt/V urea. ASAIO Trans. 1987;33:286-8.
33. Borzou SR, Gholyaf M, Zandiha M, Amini R, Goodarzi MT, Torkaman B. The effect of increasing blood flow rate on dialysis adequacy in hemodialysis patients. Saudi J Kidney Dis Transpl. 2009;20:639-42.
34. Ouzouni S, Kouidi E, Sioulis A, Grekas D, Deligiannis A. Effects of intradialytic exercise training on health-related quality of life indices in haemodialysis patients. Clin Rehabil. 2009;23:53-63. doi: 10.1177/0269215508096760.
35. Kong CH, Tattersall JE, Greenwood RN, Farrington K. The effect of exercise during haemodialysis on solute removal. Nephrol Dial Transplant. 1999;14:2927-31. doi: 10.1093/ndt/14.12.2927.
36. Kugler C, Maeding I, Russell CL. Non-adherence in patients on chronic hemodialysis: an international comparison study. J Nephrol. 2011;24:366-75. doi: 10.5301/jn.2010.5823.
37. Szeto CC, Wong TY, Leung CB, Wang AY, Law MC, Lui SF, et al. Importance of dialysis adequacy in mortality and morbidity of chinese CAPD patients. Kidney Int. 2000;58:400-7. doi: 10.1046/j.1523-1755.2000.00179.x.
38. Dashti A, Shahgholian N, Mafi M, Goudarzi F, Hoseinigolafshani SZ. How to increase dialysis adequacy; a randomized clinical trial. J Nephropathol. 2020;9:e09. doi: 10.15171/jnp.2020.09.