Review

Physical Exercise of Patients on Hemodialysis, Optimistic or Pessimistic

Radojica V. Stolic, Natasa Zdravkovic, Vekoslav Mitrovic, Andrijana Karanovic, Dragisa Rasic, Kristina Bulatovic

University of Kragujevac, Medical Faculty Kragujevac, Serbia

Keywords. physical exercise, hemodialysis, barriers, risks of exercise, expected benefits

Chronic kidney disease leads to significant functional limitations and severe disability, which requires the application of an appropriate physical rehabilitation strategy that helps patients achieve social well-being and significant health benefits.

Data sources MEDLINE, PubMed, Google Scholar and Web of Science were electronically searched, by using search terms: physical exercise, hemodialysis, barriers, risks of exercise, expected benefits. The contraindications for exercise are recent myocardial infarction, uncontrolled arrhythmia and hypertension, unstable angina pectoris, unregulated diabetes mellitus, the presence of neurological and muscular dysfunctions, malignancies, and pregnancy.

The implementation of the physical exercise program for hemodialysis patients confirmed all the expected benefits: improvement of cardiovascular functions, stabilization of blood pressure, increased muscle strength, improvement of nutritional status and quality of dialysis, reduction of negative emotions, anxiety and depression, as well as social interaction of patients and their families.

Despite the fact that a large number of studies have proven the beneficial effects of exercise during hemodialysis, a physical rehabilitation program as a standard form of treatment has not yet been introduced.

Although there is no doubt that the effects of physical activity on the survival and the quality of life of patients on hemodialysis are positive, rehabilitation program still falls under the routine practice program in a small number of dialysis centers. One of the biggest obstacles to the implementation of the physical therapy program in hemodialysis patients is the lack of a clearly defined program that defines all the needs of dialysis patients.

IJKD 2023;17:229-37
www.ijkd.org
DOI: 10.52547/ijkd.7570

INTRODUCTION

Chronic diseases are major challenges in health systems that impose enormous costs on health care systems.[1] Among chronic diseases, chronic kidney disease (CKD) is now considered one of the main health problems in the world.[2] There are about 3,730,000 patients with chronic kidney disease worldwide, with an annual growth rate of 5 to 6%.[1] It is expected that this patient population will almost double by 2030 (about 4.5 million).[3,4] As a result, the percentage of patients with multiple disabilities is increasing, and complications associated with dialysis, including malnutrition, amyloidosis, and skeletal and joint damage, are

still major problems that significantly reduce the quality of life of these patients.[5-10]

Patients on hemodialysis have significantly lower tolerance to exertion, reduced endurance and muscle strength, as well as reduced overall functional capacity. In a large observational study, it was found that reduced exercise capacity is associated with poorer survival, and the accompanying loss of muscle mass, and changes in body composition are predictors of increased mortality.[11,12]

According to the definition of the World Health Organization, rehabilitation is a complex process of retraining for activities of daily and professional life and for the emotional and social stability of persons who lose their ability due to illness or injury, with the purpose of creating conditions for reducing disability and enabling people with disabilities to achieve optimal social integration.[13]

METHODOLOGY

The most important databases we searched were MEDLINE and PubMed, but we also used Google Scholar, as well as Web of Science. The search terms that we used were: end-stage kidney disease, hemodialysis, exercise, physical function, physiotherapy, and muscle strength.

This is a systematized review about importance and impact of physical exercise on the quality of life and treatment of patients on chronic hemodialysis.

A literature review was conducted at end of 2022. The search was time-limited from 1981 to 2021. In this systematized review the data were presented under the following topics: functional disability of dialysis patients; physical fitness parameters; inactivity and muscle atrophy; muscle strength; malnutrition and physical activity; significance of physical activity in hemodialysis patients; physical rehabilitation program; the effect of physical activity on the ability to become independent; the dilemmas about benefits and risk assessment of physical rehabilitation; challenges and misconceptions of physical exercise; contraindication for the implementation of exercise programs.

Data sources including the MEDLINE, PubMed, Google Scholar and Web of Science were electronically searched. After the initial search, all articles were retrieved and reviewed by the first author, who performed the initial duplicate screening and removal. Publications reporting on the physical exercise of patients on hemodialysis in relation to the key words were selected in the literature review.

The search query was defined by keywords: physical exercise, hemodialysis, barriers, risks of exercise, expected benefits.

FUNCTIONAL DISABILITY OF DIALYSIS PATIENTS

Patients older than 75 years are the fastest growing part of the population. When they start dialysis depuration,[14] they have lots of comorbidities that lead to significant disabilities, requiring constant care to perform daily activities.[15] The etiology of disability is multifactorial and can be divided into two main categories: atherosclerotic and non-atherosclerotic group of diseases. In patients on hemodialysis, atherosclerosis progresses much faster than in the population with preserved renal function.[16] In many cases, both cardiovascular diseases and disorders of the musculoskeletal system can coexist, leading to a prolonged functional disability. In such conditions, it is challenging to determine which disease has greater impact on restricting daily activities. In addition, dialysis-related disorders and symptoms, such as depression, cognitive disorders, visual disorders, and degenerative joint disease, may exacerbate or possibly be the main cause of functional deficits.[17]

The Barthel index for daily living activities is an index of the values of basic activities of daily life such as nutrition, bathing, personal hygiene, clothing, toilet use, bowel and bladder emptying, transportation use, walking and climbing stairs, which measures functional independence in personal daily activities and needs for supervision or support. According to the Barthel index, 80 to 100 points represent independence from other people, including patients who are completely independent with 100 points; 60 to 79 points are minimally dependent persons; 40 to 59 points are partially dependent; 20 to 39 points represent highly dependent patient; and < 20 points are completely dependent on others.[18]

Gołębiowski *et al.*[19] found that disability is common in individuals with end-stage kidney disease. Half of the surveyed population (48% of patients) were functionally dependent, and their Barthel index was less than 80 points, suggesting that they need support in at least one part of physical activity. The second conclusion of their

study was that cardiovascular complications were the leading cause of disability, while the third conclusion was the presence of a statistically significant correlation between vascular changes as characterized by vascular calcification and the level of disability assessed by the Barthel index.

PHYSICAL FITNESS PARAMETERS

Inactivity and Muscle Atrophy

In patients with end-stage kidney disease, inactivity is believed to be a significant contributor to the physical impairment, reduced exercise capacity, and eventually muscle mass loss. Hemodialysis patients are significantly less active and over time their physical activity decreases by 3.4% every month.[12] The average life expectancy of physically inactive individuals is almost five years shorter than those who are physically active.[20]

Numerous metabolic and nutritional issues are associated with increased muscle degradation and impaired regeneration, which result in decreased skeletal muscle mass in patients with chronic kidney disease.[21] The accelerated degradation of proteins without a sufficient synthesis leads to atrophy of skeletal muscles, which make up 40% of human body weight.[22,23] Several reports have revealed that in addition to general factors that lead to decreased muscle mass in these patients, the accumulation of uremic toxins such as indoxyl sulfate, metabolic acidosis, malnutrition, excess angiotensin 2, myostatin levels and vitamin D deficiency are particularly associated with muscle atrophy.[21]

Muscle Strength

Muscle strength of patients on hemodialysis is not correlated with muscle mass. Muscle strength can decrease despite maintained or increased muscle mass. This is especially interesting as there are several therapeutic approaches to maintain or increase muscle mass or muscle strength.[24] Muscle strength and aerobic capacity are limited in hemodialysis patients and uremic intoxication, anemia, mineral and metabolic disorders may explain low physical performance of this patient population.[12]

MALNUTRITION AND PHYSICAL ACTIVITY

Increasing muscle strength is the most efficient method to support lipid synthesis in muscles and to reduce their catabolism that would otherwise lead to muscle fiber hypertrophy.[25-30] Kouidia *et al*.[26] and Sakkas *et al*.[30] in their studies about the muscle fiber morphology of hemodialysis patients during the regular physical activity, after six months of exercise, found a reduction in tissue atrophy from 21% to only 2%.

The goal of physical rehabilitation for hemodialysis patients improves physical condition so that the patient can move around safely and independently for a long time.[31] Gutman *et al.* found that 60% of hemodialysis patients are completely or partially independent on others' help, 20% are independent only at home, and 20% are completely dependent on other people.[32]

One third of hemodialysis patients require assistance to carry out their regular daily tasks. The criteria of improving physical activity are energy, perception of general health, and changes in health behavior, since they serve as indicators of both muscular strength and life quality. A moderately strong level of exercise improves the level of physical fitness, diet, and quality of life of patients on hemodialysis.[33] Malnutrition, loss of muscle mass, and muscle weakness are directly correlated with the reduced physical activity, which has a negative impact on the physical state of hemodialysis patients. One contributing factor is the sedentary lifestyles of these individuals, who spend 600 to 1000 hours (4 to 6 weeks) a year in sitting or lying position.[31]

Physical activity is recognized as a key component in enhancing the quality of life of hemodialysis patients, because it helps to decrease the progression of renal dysfunction, reduces pain, improves the walking capacity and strength of the extensor muscles of the knee and lower extremities. Some studies have reported that muscle strength increased by as much as 82% after three months of exercise.[34,35]

SIGNIFICANCE OF PHYSICAL ACTIVITY IN HEMODIALYSIS PATIENTS

Physical practice is not the same entity as exercise. Physical activity refers to any body movement that is initiated by the contraction of skeletal muscles, while exercise refers to a structured, planned, repetitive, and purposeful physical activity. Any physical activity that enhances physical fitness and aerobic capacity is considered exercise. It is

useful for the physical and mental health of dialysis patients and improves cardiovascular function, arterial blood pressure, muscle strength, as well as the nutritional status and quality of dialysis. Therefore, it is necessary to assess the level of physical activity in this group of patients and motivate them to actively participate in exercise.[36,37]

Regular physical activity among hemodialysis patients reduces the risk of cardiovascular mortality and hypertensive crises and improve diabetes control. The accumulation of toxic substances in the blood of patients with end-stage kidney disease causes mild fatigue, mental disorders, peripheral circulatory disorders and muscle dysfunction. Exercise during hemodialysis can minimize these changes, increase blood flow to peripheral tissues, and increase muscle perfusion.[38]

Active exercises with or without strengthening the muscle strength, cycling, resistance exercises to strengthen the muscle, and stretching exercises are examples of therapeutic modalities of exercises that are advised to patients on hemodialysis. Although many studies show the advantage of regular exercise in hemodialysis patients, it is still not established as a routine procedure.[38] Medium- and high-intensity exercise increases the maximum oxygen consumption in tissues, improves the level of physical activity, increases muscle mass and quality of life, and is useful in regulating hypertension, especially in those over 50.[39]

Despite the fact that a large number of studies have proven the beneficial effects of exercise during hemodialysis, there are few dialysis units that have introduced exercise as a standard type of treatment. Therefore, it is extremely important to overcome all obstacles regarding the implementation of physical exercise strategy in this population.[40]

PHYSICAL REHABILITATION PROGRAM

Based on the physical and functional evaluation, physiatrists design a rehabilitation program, which could anticipate the time and type of intervention in order to overcome the limitations and assess the functional goals that can be achieved.[13,51] It is important to know that there are specific rules for conducting physical activity in hemodialysis patients in whom, the maximum physical load is 51% of the load of the healthy, inactive population. The general principles for initiating any type of treatment for physical rehabilitation in hemodialysis patients are similar, suggesting a good initial assessment, a low tolerance level at the beginning of exercise, and gradual physical activity.[42] The Center for Disease Control and Prevention and the American Heart Association recommends at least 150 minutes of moderate physical activity weekly, i.e., 30 minutes at least for 5 days.[43]

Exercise has significant positive effects, so it is reasonable to ask why organized physical exercise is not well accepted and applied appropriately among dialysis patients. The lack of a clearly defined program is probably an obstacle to the implementation of the exercise program. The apprehension toward an increased level of physical activity represents a potential barrier in the context of adopting or encouraging exercise. Moderate exercise is recommended for 30 minutes or more, several days a week, which increases fitness, especially in individuals whose basic level of physical activity is extremely low.[44]

The exercise methods proposed for patients with progressive chronic kidney disease include a supervised outpatient program in the rehabilitation center, a physical rehabilitation program at home, and an exercise program during hemodialysis.[45]

Almost any increase in the physical activity of dialysis patients will bring benefits, even with an initially low level of exercise. Nevertheless, despite a variety of established advantages associated with physical activity, individuals undergoing dialysis treatment exhibit a marked lack of participation in exercise. The reasons are numerous, and the most common ones are the lack of recommendations regarding the degree, type, and level of physical activity, as well as the fear of side effects that the physical treatment can cause.[46,47]

The DOPPS study provided the first description of the international exercise patterns, as well as the link between the exercise programs and clinical outcomes of hemodialysis patients. The study that evaluated the frequency of regular physical exercise in hemodialysis patients found that 47.4% of hemodialysis patients exercise regularly. There is a positive correlation between regular training and the ability to walk independently, and reduce obesity, have better sleep quality, have greater pain tolerance, and have a better appetite, while a negative correlation is achieved in relation to age and the number of comorbidities. The results of

the DOPPS study confirmed that the mortality rate was lower in patients who had physical activity at least once a week and that the risk of mortality decreased with increasing exercise frequency. The mortality risk of physically inactive patients is 62% higher than that of physically active patients. Just 45 minutes of aerobic exercise each week for one year significantly reduce cardiovascular mortality and improve the quality of life.[20,48]

According to the KDOQI guidelines, all dialysis patients should be encouraged and advised to increase their level of physical activity (Guideline 14.2). The assessment of physical fitness and reassessment of the physical activity programs related to cardiovascular disease should be performed at least once every six months (Guideline 14.3b).[49]

Unfortunately, despite the existing recommendations, it is obvious that nephrologists do not deal with these issues in their everyday practice. The susceptibility of this patient population serves as a barrier o the introduction of more extreme exercise techniques.[44]

Measures to implement the physical rehabilitation among the dialysis population require the participation of professionals in the exercise process, commitment of the dialysis staff, careful assessment of the patients' physical fitness, individual adjustment to the exercise program, adoption of the intradialytic exercise program, avoidance of the repetitive exercise, regular assessment of the patients' physical ability, use of the methods of quantification of physical strength and provision of the adequate equipment. An integral part of all these measures is certainly the commitment of the dialysis staff, as well as the need to accept exercise as an integral component of the care of hemodialysis patients.[34]

EFFECT OF PHYSICAL ACTIVITY ON THE ABILITY TO BECOME INDEPENDENT

The evidence shows that quality of life is directly correlated with daily physical activity in patients on chronic hemodialysis. The quality of life is an individual's perception of his or her situation, which is determined by the socio-cultural level of the social community, goals and the individual's objectives and beliefs. One of the influential factors that can contribute to the physical activity and healthy lifestyle of patients on hemodialysis is their individual perception about the benefits and obstacles of exercise.[50,51]

The role of physical rehabilitation and effectiveness of the exercise program are clearly defined in hemodialysis patients in the current framework and it requires adequate patient selection, assessment of the physical activity and verification of possible contraindications, especially in patients with a poor clinical picture. Nevertheless, we are witnesses to the fact that the protocols for exercise, evaluation, and training of patients on hemodialysis are not well defined, so further research is needed to give priority to physiotherapy and functional improvement of the health of patients on hemodialysis.[35]

DILEMMAS ABOUT BENEFITS AND RISK ASSESSMENT OF PHYSICAL REHABILITATION

The prevalence of musculoskeletal complications increases with years of dialysis, which, among others, are responsible for the rapid deterioration of functional abilities necessary for independent living. The most common symptoms of such disorders are pain, deceased mobility, reduced muscle strength, early fatigue, which is described as weakness, the feeling of exhaustion, and lack of energy.[12] The prevalence of fatigue in hemodialysis patients approaches 60 to 97% and can be three times higher than in the healthy population.[46]

Decreased muscle mass is a common complication that affects patients on hemodialysis, and is associated with decreased muscle function.[52] Olvera-Soto *et al.*,[53] found that the resistance exercises with the elastic exercise bands, performed twice a week, improve muscle mass and strength. In addition, Desai *et al.*,[54] showed that muscle function and strength of patients improved after a four-month exercise program, which was arranged three times a week. Borregard *et al.*,[55] as well as the results of their own research [47] found that the benefits of exercise twice a week during dialysis for 20 minutes in patients on hemodialysis increase muscle strength and physical fitness.

Despite many proven benefits of exercise, dialysis patients are particularly inactive. The reasons are numerous and the most common ones are the lack of recommendations regarding the degree, type and level of physical activity, as well as the fear of side effects that the physical treatment can cause in this

patient population. There are several reasons for the positive effect of exercise during hemodialysis: First, there is a possibility of better adherence to the dialysis regimen. Second, hemodialysis due to forced inactivity further contributes to the poor functioning of this population, so exercise during dialysis counteracts the negative impact of dialysis. Third, it is possible that exercise improves the removal of uremic toxins due to the increased blood flow in the muscles of the extremities.[56]

The use of physical rehabilitation is still uncommon in most dialysis units; that is, patients arrange physical treatment, as long as the dialysis center has developed an exercise culture, with motivation being a key factor. One of the main reasons for this condition is the heterogeneity of dialysis patients, which is why it is necessary to individualize exercise programs according to the patients' physical abilities and comorbidities.[34]

The risk assessment of patients on chronic hemodialysis must be determined on an individual basis before the initiation of physical rehabilitation to avoid exceeding the capacity of physical activity. The risk will be minimized if the patient quickly reports certain reactions or symptoms, indicating when it is important to lessen the intensity, postpone, or stop the activity.[57]

Fatigue is reported most often in hemodialysis patients and it negatively affects their clinical condition.[33]

CHALLENGES AND MISCONCEPTIONS OF PHYSICAL EXERCISE

The most common conditions that necessitate caution during exercise in hemodialysis patients are unstable blood pressure and problematic use of the extremities on which the vascular access was created. In addition to disrupting the routine of the dialysis procedure itself, some patients describe feeling uncomfortable to exercise in front of others.[58]

Because patients with end-stage kidney disease are at an increased risk for cardiovascular morbidity, the existing guidelines provide little help on whether the additional tests should be performed before starting the exercise program. The prevailing opinion is that patients with suspected or known heart disease must pass the additional tests, especially if higher-intensity physical activity is planned. If moderate-intensity exercise is planned, then a medical history, physical examination, and ECG are sufficient for participating in the exercise program.[42]

The most common challenges and obstacles to exercise among patients with chronic kidney disease are poor physical functions, as a consequence of the burden of various comorbidities, as well as numerous psychological and logistic issues. The specific symptoms associated with these comorbid conditions include chronic pain, fatigue, dyspnea, cardiovascular disease, diabetes mellitus, and muscle wasting. The cognitive and psychological barriers were also highlighted, including the fear of falling, decreased motivation, depression, feelings of fear of the dialysis staff, and uncertainty regarding the positive effects of exercise. The logistical barriers include the limited access to exercise facilities, transportation problems, and restricted dialysis prescription schedules.[59]

The organizational challenges for exercise among patients with chronic kidney disease, who have not started dialysis treatment yet, may be the lack of information, social interaction and support, as well as challenges in the physical environment. Patients with chronic kidney disease often feel that their health care team does not prioritize exercise and that they lack a tailored advice and support from their healthcare professionals. Although patients indicated that social interaction would be a useful component of the exercise program, they described a lack of support network among renal patients to improve self-confidence, acceptance, and association with the physical rehabilitation program.[59]

The structural barriers to exercise in hemodialysis patients are the lack of resources for exercise and training among the service providers and dialysis staff regarding their role in assessing and encouraging physical activity. The strength training equipment is often lacking and is rarely available to a large number of dialysis patients, as it is too bulky or expensive. A small number of institutions have a specialized exercise worker who could promote physical activity appropriately, without leaving this burden to the medical staff, who may lack motivation, time, training or expertise.[59]

Some of these problems may be due to the disagreements between patients and the medical staff regarding the perception of the exercise program. One survey showed a mismatch between

the patients' high levels of interest in exercise (90%) and nephrologists' misconceptions about the patients' lack of interest. In addition, the dialysis staff described their patients as being less interested in exercise. While most patients also believe that they will achieve significant health benefits from the increased levels of physical activity, only 45% of nurses at the clinic believe that most patients would benefit from the regular exercise. Physicians (40%) appear to be much more concerned about the risks of exercise than patients themselves (8%), which is another barrier to promoting physical activity.[43]

The information collected so far from physicians and patients suggest that physicians need both the equipment and training, as well as the incentive to recommend implementation of the exercise program. It is also necessary to make efforts to change the attitude of patients who claim that they do not have enough time and have too many health problems for active exercise, without being aware of the number of comorbidities present without physical activity. This suggests that patients' perceptions of the burden of their disease may be more relevant than their comorbidities. The patients' emphasis on time and workload is important because it has implications for an individual's motivation to increase their physical activity.[60]

CONTRAINDICATION FOR IMPLEMENTATION OF EXERCISE PROGRAMS

Physical exercise programs should be applied with caution in patients with recent heart attacks, uncontrolled arrhythmias and hypertension, unstable angina pectoris, uncontrolled diabetes, and impaired left ventricular function. Presence of neurological and muscular dysfunctions, malignancies, and pregnancy are absolute contraindications for exercise. In addition, physical rehabilitation may be stopped in cases of profound fatigue, chest pain, dizziness, faint, syncope, dyspnea, arrhythmia, hypotension or uncontrolled hypertension.[35]

The static and dynamic high-intensity exercise, sudden changes of position or exercise with arms above the head are strictly prohibited, but any physical activity is strictly contraindicated in patients with arrhythmia at rest, as well as tachycardia or bradycardia with an unknown source.[61]

CONCLUSION

So far, the data and recommendations of the nephrology profession indicate that regular, controlled, and individualized physical exercise has considerable benefits. Implementation of the exercise programs for hemodialysis patients has confirmed the expected optimism in terms of improving cardiovascular function, blood pressure control, increasing muscle strength, improving nutritional status and dialysis quality, reducing negative emotions, anxiety and depression, and social interaction of patients and their families. The mortality rate is lower in patients who have physical activity at least once a week and the risk of mortality decreases with increasing of the exercise frequency. Other benefits of the regular exercise imply improved lung capacity, endothelial function, lipid status, and reduced markers of inflammation.

REFERENCES

1. Epping-Jordan J, Bengoa R, Kawar R, Sabaté E. The challenge of chronic conditions: WHO responds. BMJ. 2001; 323(7319): 947–48.
2. Ahmadpour B, Ghafourifard M, Ghahramanian A. Trust towards nurses who care for haemodialysis patients: a cross-sectional study. Scand J Caring Sci. 2019; 34: 1010–106.
3. Brück K, Stel VS, Gambaro G, et al. on behalf of the European CKD Burden Consortium: CKD Prevalence Varies across the European General Population. Journal of the American Society of Nephroloy. 2016; 27(7): 2135-47.
4. Bikbov B, Purcell CA, Levey AS, et al. Global, regional, and national burden of chronic kidney disease, 1990–2017: a systematic analysis for the global burden of disease study 2017. Lancet. 2020; 395(10225): 709–33.
5. Brahee DD, Guebert GM, Virgin B. Dialysis-related spondyloarthropathy. J Manip Physiol Ther. 2001; 24: 127–30.
6. Charra B, Calemard E, Uzan M, Terrat JC, Vanel T, Laurent G. Carpal tunnel syndrome, shoulder pain and amyloid deposits in long-term haemodialysis patients. In Proceedings of the European Dialysis and Transplant Association-European Renal Association; Congress: Washington, DC, USA. 1985; (21): 291–95.
7. Hoshino J, Yamagata K, Nishi S, et al. Carpal tunnel surgery as proxy for dialysis-related amyloidosis: Results from the Japanese society for dialysis therapy. Am J Nephrol. 2014; 39: 449–58.
8. Kazama JJ, Yamamoto S, Takahashi N, et al. Abeta-2M-amyloidosis and related bone diseases. J Bone Miner Metab. 2006; 24: 182–84.
9. Labriola L, Jadoul M. Dialysis-related Amyloidosis: Is It Gone or Should It Be? Semin Dia. 2017; 30: 193–96.

10. K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease. Am J Kidney Dis. 2003; 42: S1–S201.
11. Tavolaro A, Baronti M.E, Giannese D, Cupisti A. Dialysis Exercise Team: The Way to Sustain Exercise Programs in Hemodialysis Patients. Kidney Blood Press Res. 2014; 39: 129-33. doi:10.1159/000355787.
12. Kosmadakis GC, Bevington A, Smith AC, et al. Physical Exercise in Patients with Severe Kidney Disease. Nephron Clin Pract. 2010; 115: c7–c16. doi. org/10.1159/000286344.
13. Intiso D. The Rehabilitation Role in Chronic Kidney and End Stage Renal Disease. Kidney Blood Press Res. 2014; 39: 180-88. DOI:10.1159/000355795.
14. United States Renal Data System. 2018 USRDS Annual Data Report: Epidemiology of Kidney Disease in the United States. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; Bethesda, MD, USA: 2018.
15. McAdams-Demarco MA, Law A, Garonzik-Wang JM, et al. Activity of daily living disability and dialysis mortality: Better prediction using metrics of aging. J Am Geriatr Soc. 2012; 60: 1981–982. doi: 10.1111/j.1532-5415.2012.04161.x.
16. Levey AS, de Jong PE, Coresh J, et al. The definition, classification, and prognosis of chronic kidney disease: A KDIGO Controversies Conference report. Kidney Int. 2011; 80: 17–28. doi: 10.1038/ki.2010.483.
17. Farragher J, Jassal SV. Rehabilitation of the geriatric dialysis patient. Semin Dial. 2012; 25: 649–56. doi: 10.1111/sdi.12014.
18. Wade DT, Collin C. The Barthel ADL Index: A standard measure of physical disability? Int. Disabil Stud. 1988; 10: 64–7. doi: 10.3109/09638288809164105.
19. Gołębiowski T, Kusztal M, Konieczny A, et al. Disability of Dialysis Patients and the Condition of Blood Vessels; J Clin Med. 2020; 9(6): 1806. doi: 10.3390/jcm9061806.
20. Giuseppe A, Valentea L, Catizone L. The Role of Physical Activity in the CKD Setting. Kidney Blood Press Res. 2014; 39: 97-06.
21. Ishikawa S, Naito S, Iimori S, et al. Loop diuretics are associated with greater risk of sarcopenia in patients with non-dialysis-dependent chronic kidney disease. PLoS One. 2018; 15; 13(2): e0192990.
22. Chen CT, Lin SH, Chen JS, Hsu YJ. Muscle Wasting in Hemodialysis Patients: New Therapeutic Strategies for Resolving an Old ProblemScientific World Journal. 2013; 2013: 643954.
23. Stenvinkel P, Carrero JJ, von Walden F, Ikizler TA, Nader GA. Muscle wasting in end-stage renal disease promulgates premature death: established, emerging and potential novel treatment strategies. Nephrol Dial Transplant. 2016; 31(7): 1070-77.
24. Isoyama N, Qureshi AR, Avesani CM, et al. Comparative associations of muscle mass and muscle strength with mortality in dialysis patients. Clin J Am Soc Nephrol. 2014; 7; 9(10): 1720-28.
25. Stolic R, Trajkovic G, Stolic D, Peric V, Subaric-Gorgieva G. Nutrition parameters as hemodialysis adequacy markers. HIPPOKRATIA. 2010; 14 (3): 193-97.
26. Kouidi E, Albani M, Natsis K, et al. The effects of exercise training on muscle atrophy in hemodialysis patients. Nephrol Dial Transplant. 1998; 13(3): 685-99.
27. Castaneda C, Grossi L, Dwyer J. Potential benefits of resistance exercise training on nutritional status in renal failure. J Ren Nutr. 1998; 8(1): 2-10.
28. Campbell WW, Crim MC, Young VR, Joseph LJ, Evans WJ. Effects of resistance training and dietary protein intake on protein metabolism in older adults. Am J Physiol. 1995; 268(6 Pt 1) E1143-153.
29. Castaneda C, Gordon PL, Uhlin KL, et al. Resistance training to counteract the catabolism of a lowprotein diet in patients with chronic renal insufficiency. A randomized control trial. Ann Intern Med. 2001; 135(11): 965-76.
30. Sakkas GK, Sargeant AJ, Mercer TH, et al. Changes in muscle morphology in dialysis patients after six months of aerobic exercise training. Nephrol Dial Transplant. 2003; 18(9): 1854-861.
31. Mahrova A, Svagrova K. Exercise Therapy – Additional Tool for Managing Physical and Psychological Problems on Hemodialysis. “Hemodialysis”, book edited by Hiromichi Suzuki. ISBN 978-953-51-0988-4, Published: February 27, 2013 DOI: 10.5772/53058.
32. Gutman R, Stead WW, Robinson RR. Physical capacity and employment status in patients on maintenance dialysis. Engl J Med. 1981; 304(6): 309-13.
33. Yurdalan US. Physiotherapy in the patients on hemodialysis. Editor: Hemodialysis; Book Editor: Hiromichi Suzuki. ISBN: 978-953-51-0988-4. http://www.intechopen.com/books/hemodialysis.
34. Capitanini A, Lange S, D’Alessandro C, et al. Dialysis Exercise Team: The Way to Sustain Exercise Programs in Hemodialysis Patients. Kidney Blood Press Res. 2014; 39: 129-33.
35. Silva SF, Pereira AA, Silva WA, Simoes R, Barros Neto Jde R. Physical therapy during hemodialyse in patients with chronic kidney disease. J Bras Nefrol. 2013; 35(3): 170-76.
36. Ghafourifard M, Mehrizade B, Hassankhani H, Heidari M. Hemodialysis patients perceived exercise benefits and barriers: the association with health-related quality of life. BMC Nephrol. 2021; 22: 94. https://doi.org/10.1186/s12882-021-02292-3.
37. Wilund KR, Jeong JH, Greenwood SA. Addressing myths about exercise in hemodialysis patients. In: Seminars in dialysis: 2019: Wiley Online Library; 2019. p. 297–02.
38. Silva LC, Marinho PE. Knowledge among nephrologists about the importance of exercise in the intradialytic period. J Phys Ther Sci. 2015; 27(9): 2991-994.
39. Chen JL, Godfrey S, Ng TT, et al. Effect of intra-dialytic, low-intensity strenght on functional capacity in adult haemodialysis patients: a randomized pilot trial. Nephrol Dial Transpl. 2010; 25(6): 1936-943.
40. Parker K. Intradialytic exercise is medicine for hemodialysis patients. Curr Sports Med Rep. 2016; 15(4): 269-75.
41. Stolić RV, Mihailović B, Matijašević IR, Jakšić MD. Effects of physiotherapy in patients treated with chronic hemodialysis. Biomedicinska istraživanja. 2018; 9(1): 103–11. doi: 10.7251/BII1801103S.

42. Kutner NG. Kidney disorders: end stage renal disease/ dialysis. In: JH Stone, M Blouin, editors. International Encyclopedia of Rehabilitation. Available online: http:// cirrie.buffalo.edu/encyclopedia/en/article/284/, 2012.
43. Delgado C, Johansen KL. Barriers to exercise participation among dialysis patients. Nephrol Dial Transplant. 2012; 27(3): 1152-157.
44. Johansen KL. Exercise and dialysis. Hemodialysis International. 2008; 12: 290–00.
45. Aucellaa F, Lucio G, Catizone VL. The Role of Physical Activity in the CKD Setting. Kidney Blood Press Res. 2014; 39: 97-06.
46. Kutner N, Bowles T, Zhang R, Huang Y, Pastan S. Dialysis facility characteristics and variation in employment rates: a national study. Clin J Am Soc Nephrol. 2008; 3: 111–16.
47. Stolic R, Trajkovic G, Pavlovic V, et al. Effects of strength training program on muscle mass in patients on hemodialysis. Acta Medica Mediterranea. 2018; 34: 551.
48. Tentori F, Elder SJ, Thumma J, et al. Physical exercise among participants in the Dialysis Outcomes and Practice Patterns Study (DOPPS): correlates and associated outcomes. Nephrol Dial Transplant. 2010; 25(9): 3050–62.
49. K/DOQI Workgroup. K/DOQI Clinical practice guidelines for cardiovascular disease in dialysis atients. Am J Kidney Dis. 2005; 45(4 Suppl 3): S1–153.
50. Anding K, Bär T, Trojniak-Hennig J, et al. A structured exercise programme during haemodialysis for patients with chronic kidney disease: clinical benefit and long-term adherence. BMJ Open. 2015; 5(8): e008709.
51. Moss AH, Davison SN. How the ESRD quality incentive program could potentially improve quality of life for patients on dialysis. Clin J Am Soc Nephrol. 2015; 10(5): 888–93.
52. Rhee CM, Kalantar-Zadeh KJ. Resistance exercise: an effective strategy to reverse muscle wasting in hemodialysis patients. Cachexia Sarcopenia Muscle. 2014; 5(3): 177-80.
53. Olvera-Soto Ma, Valdez-Ortiz G, Alvarenga RL, Espinosa-Cuevas JC, de los Ángeles M. Effect of Resistance Exercises on the Indicators of Muscle Reserves and Handgrip Strength in Adult Patients on Hemodialysis. Journal of Renal Nutrition. 2016; 26(1): 53-60.
54. Desai SV, Law TJ, Needham DM. Long-term complications of critical care. Crit Care Med. 2011; 39: 371–79.
55. Borregaard S, Kruse N, Rieckert H. Exercise Training during Dialysis. Kidney & Blood Pressure Research. 2004; 27(5/6): 324-24.
56. Johansen KL. Exercise in the end-stage renal disease population. JASN. 2007; 18(6): 1845-854.
57. El Ghoul B, Daoboul Y, Korjian S, et al. Etiology of End-Stage Renal Disease and Arterial Stiffness among Hemodialysis Patients. Biomed Res Int. 2017;2017: 2543262.
58. Jhamb M, McNulty ML, Ingalsbe G, et al. Knowledge, barriers and facilitators of exercise in dialysis patients: a qualitative study of patients, staff and nephrologists. BMC Nephrol. 2016; 17: 192.
59. Roshanravan B, Gamboa J, Wilund K. Exercise and CKD: Skeletal Muscle Dysfunction and Practical Application of Exercise to Prevent and Treat Physical Impairments in CKD. Am J Kidney Dis. 2017; 69(6): 837–52.
60. Storer TW, Casaburi R, Sawelson S, Kopple JD. Endurance exercise training during haemodialysis improves strength, power, fatigability and physical performance in maintenance haemodialysis patients. Nephrol Dial Transplant. 2005; 20(7): 1429-37.
61. 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 endstage renal disease (ESRD) patiens. Clin Nephrol. 2004; 61(4): 261-74.

Correspondence to:
Radojica Stolic, MD
Professor, Faculty of Medical Sciences, University of Kragujevac, Svetozar Markovic 69, 34000 Kragujevac, Serbia
E-mail: radojica.stolic@med.pr.ac.rs

Received April 2023
Revised June 2023
Accepted August 2023