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Physical activity in kidney transplant recipients: benefits, barriers, interventions

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Abstract

Kidney transplant recipients are reported to have low levels of physical activity compared to the general population. This population is burdened by high prevalence of both traditional and non-traditional cardiovascular risk factors. Physical activity has multiple known health benefits, including reduction of cardiovascular disease risk factors, which are the most common cause of morbidity and mortality in this group. Sedentary lifestyle has been associated with poorer long-term graft outcomes and inferior quality of life. Lack of specific guidelines regarding exercise post-transplantation has been cited as one of the barriers to physical activity, alongside comorbidities and immunosuppressive drugs' side effects. Exercise interventions, leading to improved physical functioning both pre- and post-transplant, have been demonstrated to lead to improved muscle strength, overall physical functioning, as well as cardiorespiratory performance. Currently available data on physical activity in kidney transplant recipients and its role in long term management of these patients remains limited, but promising results regarding its impact on long-term outcomes highlight the need for further research and development of more precise guidelines and educational programmes for both healthcare professionals and kidney transplant recipients.

Keywords: physical activity, exercise intervention, kidney transplantation, kidney transplant recipients, cardiovascular disease

Introduction and Objectives

Physical activity (PA) is a possible intervention in kidney transplant recipients (KTRs), with the potential to improve their cardiovascular disease (CVD) risk-factor profile, mortality, as well as overall quality of life, as its impact in the general population has been widely proven(1, 2). Although empirical evidence concerning KTRs is limited in scope, exercise has been demonstrated to have positive effects post-transplantation and should be considered in long term management of KTRs.

PA is defined by the World Health Organization (WHO) as any bodily movement produced by skeletal muscles that requires energy expenditure(3). For adults, WHO recommends at least 150-300 minutes of moderate intensity moderate-intensity aerobic physical activity, or at least 75–150 min of vigorous-intensity aerobic physical activity, or an equivalent combination of both throughout the week in order to achieve health benefits, as well as muscle-strengthening activities involving all major muscle groups at least twice a week(3).

Clinical practice guideline for the care of KTRs recommends that patients follow a healthy lifestyle and exercise(4), but it doesn't further discuss the topic. At present, no precise guidelines regarding PA in KTRs have been developed.

Prevalence of physical activity is low in patients with chronic kidney disease (CKD), especially hemodialysis patients(5, 6). Kidney transplantation, the renal replacement treatment of choice in end stage renal disease (ESRD), has been found associated with improved PA levels(7). Nonetheless, sedentary lifestyle is common in KTRs.

Despite the growing interest in inclusion of exercise in the therapeutic process of KTRs, its impact on morbidity and graft-related outcomes remains uncertain. The purpose of present review is to outline current knowledge regarding possible benefits of PA in KTRs, as well as discuss existing barriers and exercise interventions that might be implemented in post-transplantation management.

Methods

A literature review was conducted using PubMed with search terms like "physical activity in kidney transplant recipients", "kidney transplantation outcomes", "obesity in kidney transplant recipients", "cardiovascular risk in kidney transplant recipients", "solid organ transplantation", "exercise interventions" and related variations. The focus was on clinical trials, double-blind randomized controlled trials, meta-analyses, systematic reviews, and other review articles. Priority was given to articles published within the last five years to ensure that the review captured the most up-to-date research in this rapidly evolving field. Case reports were not included in the review.

Impact on CVD and mortality

Kidney transplantation has been shown to reduce CVD-related morbidity and mortality compared with hemodialysis patients(8). Nevertheless, KTRs have up to 10 times the rate of fatal cardiovascular incidents of the general population(9). Well-established risk factors for CVD, such as hypertension, diabetes mellitus, dyslipidemia, obesity and metabolic syndrome are common in KTRs(9-12) and are associeted with impaired long-term graft function and pose a risk factor for graft failure(13, 14).

Sedentary lifestyle is a known risk factor of CVD(2). Physical inactivity is associated with a higher incidence hypertension, obesity, dyslipidemia and other CVD risk factors in the general population(15). It has also been associated with higher overall mortality(15).

Physical inactivity has been proven to be associated with increased mortality risk in dialysis patients(16).

Literature on the topic of the relationship between PA and CVD risk factors and cardiac death in KTRs remains limited in scope. A study of 540 KTRs has demostrated that low level of PA is associated with history of cardiovascular disease and cardiovascular deaths(17). It was found that cardiovascular mortality was respectively 11.7 and 1.7% in the least and the most physically active tertile, while all-cause mortality was 24.4 and 5.6% according to these tertiles(17). Kang et al.(18) have also found that lower levels of PA were possitively related to higher CVD risk in a study of 4043 participants. Another study of 650 KTRs has also demostrated that higher levels of PA were associated with a lower risk of cardiovascular and all-cause mortality(19).

In a study of 10,875 KTRs, whose physical function was examined using the SF-36 questionnaire, worse physical function was associated with higher mortality(20). In patients with the highest physical function, the 3-year mortality was at 3%, while in patients with lowers physical function was at 14%(20). Another study of 64 older KTRs compared their graft and health outcomes with patients aged 18-59 years and found that pretransplant inactivity and poor functional capacity were associated with inferior outcomes(21).

Impact on quality of life (QoL)

Physical activity is associated with higher life satisfaction and happiness levels in adults(22). In KTRs, physical performance, which is an important determinant of health and QoL, can be impaired in aspects such as muscle strenght(23). Mazzoni et al.(24) assessed health-related quality of life in a group of 118 physically active KTRs, 79 sedentary KTRs and 120 active healthy control subjects using the SF-36 questionnaire. Active KTRs scored higher than their inactive counterparts in multiple SF-36 scales, including Physical Functioning, General Health, Social Functioning and Mental Health(24). Another survey study of 32 participants(25) has demonstrated that greater participation in walking, higher levels of overall PA and less time spent sedentary was associated with better QoL. Regular physical activity was found to be positively associated with QoL and aerobic fitness(26).

In a small randomized control trial, Kastelz et al.(27) have studied the effects of a 12-month exercise rehabilitation program consisting of 2 day/week, 60-minute personalized, one-on-one, resistance-based exercise trainings compared with standard care alone. The study found that the exercise intervention had a positive impact on employment, global physical and mental health, with intervention group showing greater improvements(27).

Impact on allograft function

The impact of PA on kidney function appears to be positive(28-30). In healthy subjects, increasing PA levels might potentially reduce the oddss of developing CKD by 18%(30). Villanego et al. (31)have concluded in their study have found that PA has no negative impact on renal function in non-dialysis CKD patients, in fact some studies suggest that higher levels of PA might be associated with a slower rate of eGFR loss(29, 32).

In a study of 88 recent KTRs, who had been followed over the period of one year, Gordon et al.(33) found that lifestyle factors, such as greater PA and a history of non-smoking, were associated with improved graft function at the 6 month mark, with eGFR approximately 8 mL/min/1.73 m2 higher in physically active patients. The suggested mechanisms include improved perfusion and oxygen delivery to the kidney graft due to improved cardiovascular function and delayed development of atherosclerosis(33).

A large retrospective study analyzing the impact of PA on graft function of 6,055 Italian KTRs over a 10-year follow up period demonstrated that active patients maintained higher eGFR values in the long term, especially patients aged more than 50 years(34). Out of 6,055 patients, 51.6% were active, and it was found that male, non-overweight, younger patients were more likely to be physically active(34). The study serves as confirmation of the positive impact of PA on long-term graft function preservation.

Impact on obesity and weight gain

Obesity in KTRs in frequent as it mirrors its growing incidence in the general population(35, 36). Analysis of literature shows that obesity has been associated with inferior transplant outcomes, increased mortality and higher risk of graft failure(37, 38). It is also a widely known CVD risk factor and a risk factor for the development and progression of CKD(39). Due to multiple factors, such as sedentary lifestyle, dietary intake and immunosuppresive medication, KTRs are prone to weight gain(36).

Regular PA is one of the easiest to implement strategies in weight maintenance. It has been shown that KTRs that are physically active have lower body max index (BMI)(18). Another study found that 44% of patients with obesity had low PA levels(40). Heng et al.(41) in a study of 19 non-diabetic male KTRs determined that patients who had gained weight had lower adjusted energy ependiture and reduced spontaneous PA.

Barriers

It appears that PA levels among KTRs are relatively low(5, 34). Barriers to PA in this population can be devided into those pre-dating transplantation and those which arise post-transplant.

Many KTRs were previously dialysis patients, and in this population findings such as anemia, uremia, skeletal muscle atrophy, mental health issues, and comorbidities such as CVD or diabethic neuropathy may act as barriers to physical activity(42, 43). Moreover, the long hours spent on dialysis each week cause the hemodialysis patients to be less active on a daily basis than the general population(44). Some of these factors might be corrected by a kidney transplant, though some, such as bone and muscle changes, remain present post-transplant.

Immunosuppressive drugs, with their multiple side effects, might also form a more or less direct barrier to PA. Corticosteroids are associated with osteoporosis, reduced bone mass and increased risk of fractures, and thus can indirectly lead to inactivity(42). Corticosteroids and calcineurin inhibitors might cause skeletal muscle atrophy. Calcineurin inhibitors have also been associated with neurotoxic adverse events, such as tremor, neuralgia and peripheral neuropathy(45).

Billany et al.(46) conducted a phenomenological study in which 13 KTRs with no major contraindications to exercise were interviewed. Among other factors, patricipants were concerned about lack of guidance from health care professionals, potential harm exercise might cause to the graft, and lack of access to sports facilities(46) as potential barriers to PA. In another survey study, KTRs cited lack of motivation, preferrence for other activities, bad weather and fatigue as factors detracting from PA(47).

Many physicians don’t feel confident in performing physical activity counselling in the solid organ transplant recipients, citing lack of time and lack of exercise guidelines as barriers in counselling(48). Conversely, well-established exercise programmes have been identified as one of the crucial factors in lung transplant recipients having greater PA levels than KTRs(49).

Interventions

At present, there are no precise, widely-accepted guidelines on inclusion of PA in the managements of a KTR. Kidney Disease: Improving Global Outcomes (KDIGO) recomments that KTRs maintain a healthy lifestyle(4).

Fear of movement, often associated with history of cardiovascular and cerebrovascular events and inferior physical functioning, has also been found to be positively corelated with physical inactivity(50). In order to improve physical activity, optimal management of comorbidities is necessary.

In some patients, adjustment of immunosupressive regime may contribute to increase in PA(51). A randomized control study analyzed the impact of rapid steroid withdrawal on muscle structure and has found that it lead to significant improvements in muscle structure, which might contribute to better muscle function and exercise capacity(52).

Over the last decade there's been a growing interest in developing exercise training that would address KTRs specific needs and result in better long term health outcomes.

A recent meta-analysis of randomised clinical trials studying the impact of exercise interventions on patients pre- and post-transplantation offers more detailed recommentations for this patient population(53). Baker et al.(53) recommend that KTRs should aim for 150 min of moderate to vigorous PA a week or 75 of vigorous PA, both aerobic and resistance exercise. The study also recommends that appropriately trained staff (e.g., physiotherapist, sport scientist, cardiac rehabilitation specialist, other healthcare professionals with additional training) takes part in creation of a structured exercise routine based on patient's individual goals, pathophysiology, level of experience and graft status(53). For some patients, especially those with less experience with exercise, supervision might result in better complience and higher motivation levels(46, 53).

It is important to assess the patient's physical activity levels in the pre-transplant phase. Simple screening tools such as the PAVS can be used(53). Regular exercise programmes can be set up for patients awaiting transplantation(54, 55). The concept of "prehabilitation", meaning short term exercise-based programmes introduced prior to major surgery, has been found to be safe and associated with improved peri-operative outcomes(56). In KTRs, prehabilitation has been associated with improved cardiorespiratory and physical function, as well as decreased duration of post-operative hospital stay(54). In a study of 15 candidates for kidney transplantation, the participants were enrolled in an 8-week-long exercise intervention supervised by an exercise physiologist(57). The prehabilitation programme was safe, feasible

and acceptable, with 60% completion rate, and most participants found it beneficial to their overall health(57). Another study of 18 kidney transplant candidates found that a programme consisting of weekly physical therapy sessions and at-home exercises resulted in improved physical activity and high satisfaction(58). Due to limited research available, it remains unclear which type(s) of exercise are the most beneficial in the pre-transplant phase.

Conclusion

Kidney transplantation is considered the gold standard for long term treatment of end stage renal disease. Compared to hemodialysis, it's associated with lower mortality(59) and improved quality of life(60). Although the research on the impact of PA on specific risk factors associated with graft function and other health outcomes remains limited in scope, it appears that inclusion of PA in guidelines for long term management of a transplant patient could be a positive influence on CVD risk factors and an important preventive measure of cardiovascular mortality, whose prevalence in this group remains high.

KTRs commonly lead a sedentary lifestyle. The lack of additional measures, such as specific guidelines or widespread exercise programs, is an obstable that contributes negatively to levels of PA in this group. Further research focused on strengthening the body of evidence reporting the effectiveness of PA in improving long term transplant outcomes, development of specific exercise recommendations for different age groups and adjusted to local socioeconomic conditions will be fundamental in supporting health care professional in more informed and efficient introduction of PA in their management of KTRs.

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References

1. Anokye NK TP, Green C, Pavey TG, Taylor RS. Physical activity and health related quality of life. BMC public health. 2012;12.

2. Lavie CJ OC, Carbone S, Katzmarzyk PT, Blair SN. Sedentary Behavior, Exercise, and Cardiovascular Health. Circulation research. 2019;124(5).

3. Bull FC A-AS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput JP, Chastin S, Chou R, Dempsey PC, DiPietro L, Ekelund U, Firth J, Friedenreich CM, Garcia L, Gichu M, Jago R, Katzmarzyk PT, Lambert E, Leitzmann M, Milton K, Ortega FB, Ranasinghe C, Stamatakis E, Tiedemann A, Troiano RP, van der Ploeg HP, Wari V, Willumsen JF,. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. British journal of sports medicine. 2020;54(24).

4. Kasiske BL, Zeier MG, Chapman J, et al. KDIGO clinical practice guideline for the care of kidney transplant recipients: a summary. Kidney International. 2010;77(4):299-311.

5. Wilkinson TJ, Clarke AL, Nixon DGD, Hull KL, Song Y, Burton JO, et al. Prevalence and correlates of physical activity across kidney disease stages: an observational multicentre study. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association. 2021;36(4).

6. Marczyk K, Berner A, Stencel K, Pękała M, Olszewska A, et al. Physical activity of patients with chronic kidney disease. *Journal of Education, Health and Sport*. Online2023. p. pp. 152-69.

7. Nielens H, Lejeune TM, Lalaoui A, Squifflet JP, Pirson Y, Goffin E. Increase of physical activity level after successful renal transplantation: a 5 year follow-up study. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association. 2001;16(1).

8. Bottomley MJ, Harden PN. Update on the long-term complications of renal transplantation. British medical bulletin. 2013;106.

9. Liefeldt L, Budde K. Risk factors for cardiovascular disease in renal transplant recipients and strategies to minimize risk. Transplant international : official journal of the European Society for Organ Transplantation. 2010;23(12).

10. Kasiske BL, Anjum S, Shah R, Skogen J, Kandaswamy C, Danielson B, et al. Hypertension after kidney transplantation. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2004;43(6).
11. Katznelson S, Wilkinson AH, Kobashigawa JA, Wang XM, Chia D, Ozawa M, et al. The effect of pravastatin on acute rejection after kidney transplantation--a pilot study. Transplantation. 1996;61(10).
12. Cantarin MPM. Diabetes in kidney transplantation. Advances in chronic kidney disease. 2024;28(6):596.
13. Ozdemir FN, Karakan S, Akgul A, M H. Metabolic syndrome is related to long-term graft function in renal transplant recipients. Transplantation proceedings. 2009;41(7).
14. Roodnat JI, Mulder PG, Zietse R, Rischen-Vos J, van Riemsdijk IC, IJzermans JN, et al. Cholesterol as an independent predictor of outcome after renal transplantation. Transplantation. 2000;69(8).
15. Leitzmann MF, Park Y, Blair A, Ballard-Barbash R, Mouw T, Hollenbeck AR, et al. Physical activity recommendations and decreased risk of mortality. Archives of internal medicine. 2007;167(22).
16. O'Hare AM, Tawney K, Bacchetti P, Johansen KL. Decreased survival among sedentary patients undergoing dialysis: results from the dialysis morbidity and mortality study wave 2. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2003;41(2).
17. Dorien M Zelle EC, Ronald P Stolk, Mathieu HG de Greef, Rijk OB Gans, Jaap J Homan van der Heide, Gerjan Navis, Stephan JL Bakker. Low Physical Activity and Risk of Cardiovascular and All-Cause Mortality in Renal Transplant Recipients. Clinical Journal of the American Society of Nephrology : CJASN. 2011;6(4):898.
18. Kang AW, Garber CE, Eaton CB, Risica PM, Bostom AG. Physical Activity and Cardiovascular Risk among Kidney Transplant Patients. Medicine and science in sports and exercise. 2019;51(6).
19. Byambasukh O, Osté MCJ, Gomes-Neto AW, van den Berg E, Navis G, Bakker SJL, et al. Physical Activity and the Development of Post-Transplant Diabetes Mellitus, and Cardiovascular- and All-Cause Mortality in Renal Transplant Recipients. Journal of clinical medicine. 2020;9(2).
20. Reese PP, Bloom RD, Shults J, Thomasson A, Mussell A, Rosas SE, et al. Functional status and survival after kidney transplantation. Transplantation. 2014;97(2).

21. Yango AF, Gohh RY, Monaco AP, Reinert SE, Gautam A, Dworkin LD, et al. Excess risk of renal allograft loss and early mortality among elderly recipients is associated with poor exercise capacity. Clinical nephrology. 2006;65(6).
22. An HY, Chen W, Wang CW, Yang HF, Huang WT, Fan SY. The Relationships between Physical Activity and Life Satisfaction and Happiness among Young, Middle-Aged, and Older Adults. International journal of environmental research and public health. 2020;17(13).
23. Esposito P, Furini F, Rampino T, Gregorini M, Petrucci L, Klersy C, et al. Assessment of physical performance and quality of life in kidney-transplanted patients: a cross-sectional study. Clinical kidney journal. 2017;10(1).
24. Mazzoni D, Cicognani E, Mosconi G, Totti V, Roi GS, Trerotola M, et al. Sport activity and health-related quality of life after kidney transplantation. Transplantation proceedings. 2014;46(7).
25. Raymond J, Johnson ST, Diehl-Jones W, Vallance JK. Walking, Sedentary Time and Health-Related Quality Life Among Kidney Transplant Recipients: An Exploratory Study. Transplantation proceedings. 2016;48(1).
26. Macdonald JH, Kirkman D, Jibani M. Kidney transplantation: a systematic review of interventional and observational studies of physical activity on intermediate outcomes. Advances in chronic kidney disease. 2009;16(6).
27. Kastelz A, Fernhall B, Wang E, Tzvetanov I, Spaggiari M, Shetty A, et al. Personalized physical rehabilitation program and employment in kidney transplant recipients: a randomized trial. Transplant international : official journal of the European Society for Organ Transplantation. 2021;34(6).
28. Hawkins MS, Sevick MA, Richardson CR, Fried LF, Arena VC, Kriska AM. Association between physical activity and kidney function: National Health and Nutrition Examination Survey. Medicine and science in sports and exercise. 2011;43(8).
29. Robinson-Cohen C, Littman AJ, Duncan GE, Weiss NS, Sachs MC, Ruzinski J, et al. Physical activity and change in estimated GFR among persons with CKD. Journal of the American Society of Nephrology : JASN. 2014;25(2).
30. Kelly JT, Su G, Zhang L, Qin X, Marshall S, González-Ortiz A, et al. Modifiable Lifestyle Factors for Primary Prevention of CKD: A Systematic Review and Meta-Analysis. Journal of the American Society of Nephrology : JASN. 2021;32(1).
31. Villanego F, Naranjo J, Vigara LA, Cazorla JM, Montero ME, García T, et al. Impact of physical exercise in patients with chronic kidney disease: Sistematic review and meta-analysis. Nefrologia. 2020;40(3).

32. Chen I-R, Wang S-M, et al. Association of Walking with Survival and RRT Among Patients with CKD Stages 3–5. Clinical Journal of the American Society of Nephrology : CJASN. 2014;9(7):1183.
33. Gordon EJ, Prohaska TR, Gallant MP, et al. Longitudinal analysis of physical activity, fluid intake, and graft function among kidney transplant recipients. Transplant international : official journal of the European Society for Organ Transplantation. 2009;22(10):990.
34. Masiero L, Puoti F, Bellis L, Lombardini L, Totti V, Angelini ML, et al. Physical activity and renal function in the Italian kidney transplant population. Renal failure. 2020;42(1).
35. Conte C, Maggiore U, Cappelli G, Ietto G, Lai Q, Salis P, et al. Management of metabolic alterations in adult kidney transplant recipients: A joint position statement of the Italian Society of Nephrology (SIN), the Italian Society for Organ Transplantation (SITO) and the Italian Diabetes Society (SID). Nutrition, metabolism, and cardiovascular diseases : NMCD. 2020;30(9).
36. Aksoy N. Weight Gain After Kidney Transplant. Experimental and clinical transplantation : official journal of the Middle East Society for Organ Transplantation. 2016;14(Suppl 3).
37. Hoogeveen EK, Aalten J, Rothman KJ, Roodnat JI, Mallat MJ, Borm G, et al. Effect of obesity on the outcome of kidney transplantation: a 20-year follow-up. Transplantation. 2011;91(8).
38. Nöhre M, Schieffer E, et al. Obesity After Kidney Transplantation—Results of a KTx360°Substudy. Frontiers in Psychiatry. 2020;11:399.
39. Song R, Nolan BJ, Harb H, Sumithran P. Intensive management of obesity in people with severe chronic kidney disease: A review. Diabetes, obesity & metabolism. 2021;23(8).
40. Tarsitano MG, Porchetti G, et al. Obesity and Lifestyle Habits among Kidney Transplant Recipients. Nutrients. 2022;14(14):2892.
41. Heng AE, Montaurier C, Cano N, Caillot N, Blot A, Meunier N, et al. Energy expenditure, spontaneous physical activity and with weight gain in kidney transplant recipients. Clinical nutrition (Edinburgh, Scotland). 2015;34(3).
42. Takahashi A, Hu SL, Bostom A. Physical Activity in Kidney Transplant Recipients: A Review. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2018;72(3).
43. Kosmadakis GC, Bevington A, Smith AC, et al. Physical Exercise in Patients with Severe Kidney Disease. Nephron Clinical Practice. 2010;115(1).

44. Majchrzak KM, Pupim LB, Chen K, et al. Physical activity patterns in chronic hemodialysis patients: Comparison of dialysis and nondialysis days. Journal of Renal Nutrition. 2005;15(2):217-24.
45. Bechstein WO. Neurotoxicity of calcineurin inhibitors: impact and clinical management. Transplant international : official journal of the European Society for Organ Transplantation. 2000;13(5).
46. Billany RE, Smith AC, Stevinson C, Clarke AL, Graham-Brown MPM, Bishop NC. Perceived barriers and facilitators to exercise in kidney transplant recipients: A qualitative study. Health expectations : an international journal of public participation in health care and health policy. 2022;25(2).
47. Sánchez ZV, Cashion AK, Cowan PA, Jacob SR, Wicks MN, Velasquez-Mieyer P. Perceived barriers and facilitators to physical activity in kidney transplant recipients. Progress in transplantation (Aliso Viejo, Calif). 2007;17(4).
48. Pang A, Lingham S, Zhao W, et al. Physician Practice Patterns and Barriers to Counselling on Physical Activity in Solid Organ Transplant Recipients. Annals of Transplantation. 2018;23:345-59.
49. Gustaw T, Schoo E, Barbalinardo C, Rodrigues N, Zameni Y, Motta VN, et al. Physical activity in solid organ transplant recipients: Participation, predictors, barriers, and facilitators. Clinical transplantation. 2017;31(4).
50. Zelle DM, Corpeleijn E, Klaassen G, Schutte E, Navis G, Bakker SJ. Fear of Movement and Low Self-Efficacy Are Important Barriers in Physical Activity after Renal Transplantation. PloS one. 2016;11(2).
51. Painter PL, Topp KS, Krasnoff JB, Adey D, Strasner A, Tomlanovich S, et al. Health-related fitness and quality of life following steroid withdrawal in renal transplant recipients. Kidney international. 2003;63(6).
52. Topp KS, Painter PL, Walcott S, Krasnoff JB, Adey D, Sakkas GK, et al. Alterations in skeletal muscle structure are minimized with steroid withdrawal after renal transplantation. Transplantation. 2003;76(4).
53. Baker LA, March DS, Wilkinson TJ, Billany RE, Bishop NC, Castle EM, et al. Clinical practice guideline exercise and lifestyle in chronic kidney disease. BMC nephrology. 2022;23(1).
54. Quint EE, Ferreira M, van Munster BC, Nieuwenhuijs-Moeke G, Te Velde-Keyzer C, Bakker SJL, et al. Prehabilitation in Adult Solid Organ Transplant Candidates. Curr Transplant Rep. 2023;10(2):70-82.

55. Mathur S, Janaudis-Ferreira T, Wickerson L, Singer LG, Patcai J, Rozenberg D, et al. Meeting report: consensus recommendations for a research agenda in exercise in solid organ transplantation. American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons. 2014;14(10).
56. Hughes MJ, Hackney RJ, Lamb PJ, Wigmore SJ, Christopher Deans DA, Skipworth RJE. Prehabilitation Before Major Abdominal Surgery: A Systematic Review and Meta-analysis. World journal of surgery. 2019;43(7).
57. Lorenz EC, Bonikowske AR, Meter ACD-V, et al. A Multicenter Home-based Prehabilitation Intervention in Kidney Transplant Candidates. Transplantation Direct. 2024;10(12).
58. McAdams-DeMarco MA, Ying H, Van Pilsum Rasmussen S, Schrack J, Haugen CE, Chu NM, et al. Prehabilitation prior to kidney transplantation: Results from a pilot study. Clinical transplantation. 2019;33(1).
59. Neovius M, Jacobson SH, Eriksson JK, et al. Mortality in chronic kidney disease and renal replacement therapy: a population-based cohort study. BMJ Open. 2014;4(2).
60. Hussien H, Apetrii M, Covic A. Health-related quality of life in patients with chronic kidney disease. Expert review of pharmacoeconomics & outcomes research. 2021;21(1).