



Simultaneous Improvement of Habitual Physical Activity and Life Quality in Kidney Transplant Recipients Involved in Structured Physical Activity Program

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ABSTRACT

Objectives. The aim of the study was to compare the effects of a physical activity program on daily physical activity and quality of life in kidney transplant (KTx) recipients and in patients with chronic kidney disease (CKD).

Materials and Methods. The study group consisted of 24 KTx recipients and 15 patients with stage 3 to 4 CKD. Habitual physical activity was monitored for 72 hours. Individualized structured programs of increased physical activity were prepared based on baseline physical performance. The measurements were repeated after 1 and 3 months. Participants completed the 36-item Short Form Health Survey questionnaire and an International Physical Activity Questionnaire at baseline and after 1, 2, and 3 months.

Results. Physical activity duration and total energy expenditure significantly increased after 3 months in both KTx recipients (from 126 ± 87 to 200 ± 132 min/d, $P = .001$, and from 1.73 ± 0.37 to 2.24 ± 0.59 cal/min, $P < .001$, respectively) and CKD patients (from 79 ± 78 to 129 ± 114 min/d, $P < .001$, and from 1.5 ± 0.5 to 1.92 ± 0.47 cal/min, $P < .001$, respectively). Short Form Health Survey total score and physical component scale score improved significantly in both groups. Mental component scale score increased significantly only in KTx patients.

Conclusion. Increased physical activity induces similar beneficial effects on total and physical activity component of quality of life and habitual daily activity in CKD and KTx patients.

MOST patients with chronic kidney disease (CKD), including kidney transplant (KTx) recipients, have a sedentary lifestyle, which may have a detrimental effect on their survival. Patients with CKD as well as KTx recipients are at much higher risk for cardiovascular disease and mortality compared to the general population [1,2], and low physical activity has been recognized as a major modifiable risk factor for death in patients with end-stage renal disease [3]. Multiple factors arising from CKD and its comorbidities constitute harmful combinations resulting in reduced physical activity in CKD patients. The lack of physical activity—that is, a sedentary lifestyle—is a significant factor leading to the deterioration of physical condition, reduction in physical capacity, and ultimately muscle weakness in this population [4,5]. In comparison to patients receiving

chronic dialysis treatment, KTx recipients show improved quality of life [6–8]. Increased physical activity compared to the pretransplant period may result from both a correction of uremic toxicity and time saved by not having to go for hemodialysis treatment. Studies performed in various populations including patients with impaired kidney function have demonstrated that level of physical activity may independently predict mortality in CKD [9]. Increased physical

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Table 1. Baseline Clinical and Laboratory Characteristics of KTx Recipients and Patients With CKD

	All Patients (n = 39)	KTx Patients (n = 24)	CKD Patients (n = 15)	P Value (KTx patients vs CKD patients)
Sex (male/female)	18/21	11/13	7/8	
Age (y)	46.9 ± 11.8	47 ± 13	47 ± 9	.2
Body mass (kg)	77.1 ± 16.1	75.3 ± 16.8	79.8 ± 14.9	.6
Body mass index (kg/m ²)	26.8 ± 4.2	26 ± 4	27 ± 4	.9
Smoking (n)	7 (17.9%)	2 (8.3%)	5 (33.3%)	<.05
Blood parameters				
Creatinine (mg/dL)	2.2 ± 0.8	1.8 ± 0.5	2.7 ± 0.8	.03
Estimated glomerular filtration rate (mL/min/1.73 m ³)	47.1 ± 21.3	53 ± 23	36 ± 11	.006
Hemoglobin (g/dL)	13.2 ± 2.0	13.7 ± 1.8	12.4 ± 2.0	.7
Fasting glucose (mg/dL)	94.1 ± 10.9	90.5 ± 9.1	92.1 ± 8.9	.07
Total cholesterol (mg/dL)	242.3 ± 56.8	230.5 ± 45.1	261.3 ± 69.3	.06
High-density lipoprotein cholesterol (mg/dL)	49.4 ± 11.7	50.6 ± 10.1	47.5 ± 14.1	.2
Low-density lipoprotein cholesterol (mg/dL)	143.2 ± 30.8	142.9 ± 32.5	143.8 ± 28.9	.6
Triglyceride (mg/dL)	231.1 ± 141.5	200.4 ± 127.9	280.1 ± 152.5	.4
Uric acid (mg/dL)	6.9 ± 1.6	7.2 ± 1.5	6.4 ± 1.6	.8
Total protein (g/L)	70.3 ± 4.7	71.3 ± 5.4	68.7 ± 2.8	.01
Albumin (g/L)	42.1 ± 3.4	42.9 ± 3.1	40.9 ± 3.6	.6
Blood pressure				
Systolic blood pressure (mm Hg)	131.8 ± 12.6	132 ± 12	132 ± 13	.8
Diastolic blood pressure (mm Hg)	77.3 ± 9.2	76 ± 9	79 ± 9	.9
Physical activity parameters				
Total energy expenditure (cal/min)	1.68 ± 0.44	1.73 ± 0.37	1.5 ± 0.5	.2
Active energy expenditure (cal/min)	0.27 ± 0.17	0.29 ± 0.21	0.23 ± 0.17	<.0001
Metabolic equivalent (1 kcal x kg ⁻¹ x h ⁻¹)	1.4 ± 0.2	1.4 ± 0.2	1.3 ± 0.2	.006
Total number of steps	4281 ± 2154	4400 ± 2333	4091 ± 2128	.5
Physical activity duration (min)	108 ± 77.9	126 ± 87	79 ± 78	.06
Resting time (min)	563 ± 100	564 ± 102	559 ± 101	.9
Sleep duration (min)	383 ± 94	370 ± 94	402 ± 95	.9
Cause of CKD, n (%)				
Chronic glomerulopathy	16 (41)	11 (46)	5 (33)	
Polycystic kidney disease	7 (18)	4 (17)	3 (20)	
Hypertensive nephropathy	4 (10)	2 (8)	2 (13.5)	
Tubulointerstitial nephritis	5 (13)	3 (12)	2 (13.5)	
Unknown	7 (18)	4 (17)	3 (20)	

CKD, chronic kidney disease; KTx, kidney transplant.

activity achieved through different physical activity programs has been found to improve general health, cardiovascular capacity through improvement of blood pressure, serum lipids, insulin sensitivity, and inflammation [10–14]. Most studies assessing physical activity in patients with renal dysfunction have been conducted in chronic hemodialysis patients. Much less research has been focused on the assessment of physical activity and interventions aimed to increase the level of physical activity among KTx recipients or patients with predialysis CKD [15].

The aim of this study was to assess physical activity level in patients after deceased-donor KTx and CKD patients not yet on dialysis to compare the effects of an individualized structured physical activity program on the level of daily habitual physical activity and quality of life in these patients.

MATERIALS AND METHODS

The study population comprised 39 subjects (21 female, 18 male, mean age 47 ± 11 years) divided into 2 groups including 24

clinically stable KTx recipients at least 12 months after transplantation (13 women, 11 men, mean age 46 ± 13 years) and 15 nondialysis patients with CKD stage 3 and 4 (8 women, 7 men, mean age 47 ± 9 years). The study population was selected from the patients under care of the outpatient clinic at a tertiary nephrology center. Fifty patients were initially screened, but 11 (22%) of the prescreened patients refused to take part in the study. The clinical characteristics of the study population are presented in Table 1.

The inclusion criteria for KTx patients included first KTx from a deceased donor at least 12 months before the study, stable graft function, triple immunosuppressive regimen including a calcineurin inhibitor and mycophenolate mofetil, and a stable dose of prednisone for 3 months preceding the study. CKD patients were included in the study if they had stable kidney function (±5%) for at least the 6 past months and were not expected to start renal replacement therapy within the next 6 months. The exclusion criteria in both groups included hemoglobin level below 10 g/dL, diabetes mellitus, glucocorticoid therapy (daily dose of prednisone >5 mg), uncontrolled or treatment-resistant arterial hypertension (meaning a therapeutic strategy that included appropriate lifestyle plus a diuretic and 2 other antihypertensive

drugs from different classes that failed to lower systolic and diastolic blood pressure values to less than 140 and 90 mm Hg, respectively [16]), a history of stroke or myocardial infarction or unstable angina, malignancy, recent surgery, and musculoskeletal or mental disease.

The local ethics committee approved the study protocol and all procedures. All of the subjects were informed about the aims of the study and provided a written informed consent before being included in the study.

Exercise Training Program

Before exercise training was commenced, each subject underwent an extensive medical assessment consisting of physical examination, electrocardiography, and baseline measurements including the assessment of body mass index, general nutritional condition, anthropometry, body composition, and measurement of biochemical parameters. The methods used for these measurements are described in the following section.

For each patient, the 12-week program of physical activity was adjusted to the patient's baseline level of physical activity and patient preferences and consisted of a choice of endurance training involving Nordic (pole) walking, jogging, cycling, or swimming. Subjects performed the exercises 5 days per week. During the first 2 weeks, the individual training was supervised by the same qualified physiotherapist. From the third week on, the exercises were performed individually at home. During the first week, each exercise session lasted 20 minutes. The duration of exercise sessions was gradually increased to 2 hours in the fourth week. Exercise intensity was initially aimed at achieving 60%–65% of maximal heart rate and was gradually increased (approximately every 2 weeks) when tolerated by the patient up to 80% of maximal heart rate. For the

first 2 weeks, the heart rate was measured with a heart monitor during exercise to control the intensity of training.

An individualized program of increased physical activity was prepared for each subject based on the results of a physical activity assessment obtained with an accelerometer at baseline and patient preferences regarding the choice of endurance training methods. The repeated training and short message system with reminders about the benefits of physical activity were provided 3 times per week to all participants and implemented starting the second week of the training program (Fig 1). All of the measurements were repeated 1 and 3 months after the commencement of the physical activity program.

Assessment of Physical Activity

The assessments of habitual physical activity were performed at baseline for 3 consecutive days including a weekend day. They were carried out with the 3-axis SenseWear MF Armband (SWA) accelerometer (BodyMedia, Pittsburgh, Pa, United States). In accordance with the manufacturer's instructions (www.sensewear.bodymedia.com), the SenseWear Armband was placed over the triceps muscle of the right arm. The energy expenditure parameters measured with the armband included heat flux, galvanic skin response, skin temperature, and a near-body ambient temperature. The data obtained from the measurements, along with demographic characteristics (age, sex, body mass, height, right or left handedness, smoker or nonsmoker), were used to estimate the total energy expenditure, active energy expenditure, metabolic equivalent, total number of steps, physical activity duration, resting time, and sleep duration. The participants were instructed to wear the SWA continuously, taking it off only for showering, bathing, and water exercises. Participants were also instructed to



Recommended physical exercise (min/session/day)

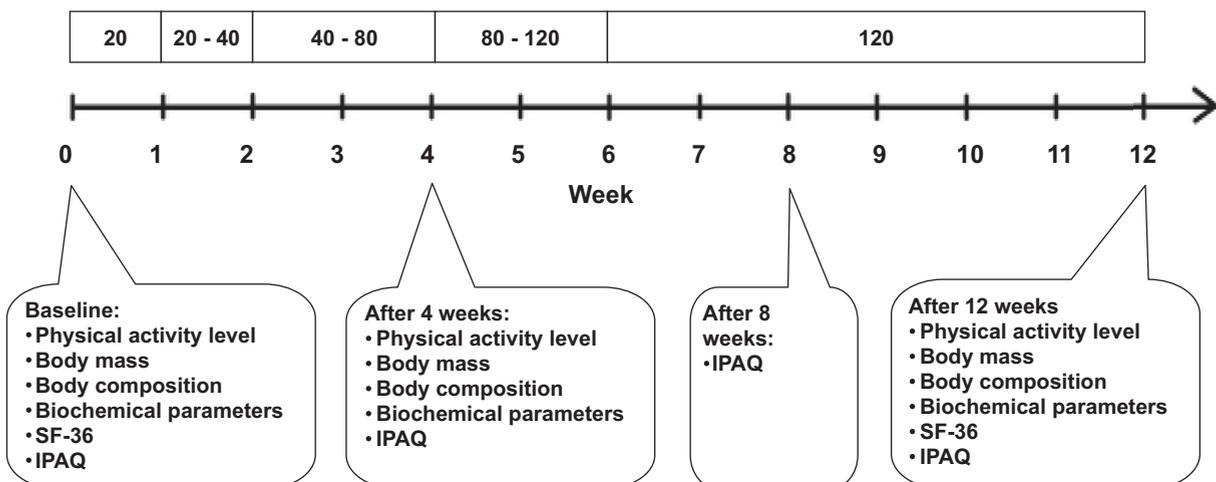


Fig 1. Study design.

call the study coordinator in case of any technical problem with the SWA. After a 3-day period, the participants were asked to switch the SWA off and return the device to the study team member by registered mail in an envelope they had been given, and the recorded data were uploaded into a computer for analysis with dedicated SWA software (SenseWear Professional software version 7.0).

Questionnaires

All participants completed the local language version of the 36-item Short Form Health Survey (SF-36) questionnaire at baseline and the end of the study and the Long Form International Physical Activity Questionnaire (IPAQ) at baseline and after 4, 8, and 12 weeks during the program. The SF-36 is a patient-reported survey of patient health and contains 36 items that assess 8 dimensions of health status: physical functioning, role limitation—physical, role limitation—emotional, social functioning, mental health, energy and vitality, bodily pain, and general health perception. Normalized scores representing overall physical and mental functioning were calculated from individual scales and presented as the physical component scale and the mental component scale. Each answer was analyzed using a score key, with a higher score indicating a better health status.

Physical activity and sitting times were measured using the long-form, past 7-day, self-administered IPAQ [17]. The version of IPAQ used for the study contained 27 questions concerning physical activity, accompanied by 4 questions providing demographic data such as sex, age, educational level, and type of professional activity. Five activity domain areas were considered: job-related physical activity; transportation physical activity; housework, house maintenance, and caring for family; recreation, sport, leisure-time physical activity; and time spent sitting. The IPAQ assesses frequency (days), duration (minutes), and intensity (light, moderate, vigorous) of physical activity. Moderate physical activity was defined as “those activities that take moderate physical effort and make you breathe somewhat harder than usual”; vigorous physical activity was defined as “those activities that take hard physical effort and make you breathe much harder than normal.”

For the analysis of the physical activity data collected from the IPAQ, a metabolic equivalent of task (MET) value was calculated for each domain separately (transportation, housework/gardening, and leisure-time activity) according to the official IPAQ guidelines and the updated Compendium of Physical Activities provided in Ainsworth et al [18]. The MET-min/wk was calculated as minutes of activity/day x days per week x MET value. The level of weekly physical activity (measured in MET-min/wk) described as high, moderate, and low intensity was determined by multiplying the number of days in which the activity was done in a week by the average length of the activity's duration in 1 day by the metabolic equivalent of the task (MET, metabolic equivalent of work = 1 kcal/kg/h) [16]. The MET value of 3.3 was adopted for low-intensity effort, MET value 4 for moderate, and MET value 8 for high.

Statistical Analysis

All results are presented as mean \pm standard deviation. A *P* value $< .05$ was considered statistically significant. Data distribution was checked with the Kolmogorov-Smirnov test, and non-normally distributed data were log transformed for further analysis. Within-group comparisons were made using analysis of variance for repeated measurements with post-hoc tests. The unpaired *t* test or Mann-Whitney test was used to

test the differences between 2 study groups. For categorical variables, the χ^2 test or Fisher's exact test was used. Statistical analysis was performed using Statistica for Windows software (version 10PL, StatSoft, Tulsa, O.K., United States).

RESULTS

Only the physically efficient patients who agreed to take part were included in the study. Seventy-five percent of the prescreened CKD patients and 30% of the prescreened KTx patients either were not physical fit or did not agree to participate in the study. In total, 26 KTx and 15 CKD patients were enrolled in the study. Twenty-four KTx patients and 14 CKD patients completed the training program and all baseline and follow-up measurements. Early cessation of the training was due to a hospitalization for pneumonia in 1 person and a family-related problem in 1 person in the KTx group, and a refusal to continue training in 1 CKD patient. As shown in Table 1, CKD and KTx patients did not significantly differ with respect to age, body mass index, serum lipids, uric acid, and blood glucose and plasma albumin concentration. Serum creatinine concentration was significantly lower and serum total protein higher in KTx patients. Fewer KTx recipients than CKD patients declared a smoking status.

Physical Activity Parameters

At baseline, only the active energy expenditure was significantly higher in KTx recipients than in CKD patients. After 3 months of participation in the exercise training program, the measures of physical activity increased significantly in both groups (Table 2). Total energy expenditure increased from 1.73 ± 0.37 to 2.24 ± 0.59 cal/min in KTx recipients and from 1.5 ± 0.5 to 1.92 ± 0.47 cal/min in CKD patients; active energy expenditure increased from 0.29 ± 0.21 to 0.44 ± 0.29 cal/min and from 0.23 ± 0.17 to 0.36 ± 0.25 cal/min, respectively; MET score increased in both groups by $0.8 \text{ l kcal} \times \text{kg}^{-1} \times \text{h}^{-1}$; total number of steps increased from 4400 ± 2333 to 9093 ± 3049 and from 4091 ± 2128 to 7291 ± 2914 , respectively. Both total energy expenditure and active energy expenditure increased significantly after 4 weeks of the exercise training program. After the next 8 weeks, the increase of active energy expenditure was not significant in both groups of patients (Table 2). The magnitude of the changes of the physical activity parameters from baseline did not differ significantly between the 2 groups of patients.

Quality of Life—SF-36

Table 3 shows the changes of SF-36 score in KTx and CKD patients induced by the exercise training program. The physical functioning and physical component score of both groups of patients significantly improved throughout the training period. The improvement of the social functioning, mental health, and mental component summary was statistically significant only in KTx patients.

Table 2. Physical Activity Parameters in Kidney Transplant Recipients and in Patients With Chronic Kidney Disease at Baseline and After 4 and 12 Weeks of Physical Activity Program

	Kidney Transplant Patients (n = 24)						Chronic Kidney Disease Patients (n = 15)					
	Baseline	After 4 Weeks	P Value (after 4 weeks vs baseline)	After 12 Weeks	P Value (after 12 weeks vs after 4 weeks)	P Value (after 12 weeks vs baseline)	Baseline	After 4 Weeks	P Value (after 4 weeks vs baseline)	After 12 weeks	P Value (after 12 weeks vs after 4 weeks)	P Value (after 12 weeks vs baseline)
Total energy expenditure (cal/min)	1.73 ± 0.37	2.1 ± 0.46	<.001	2.24 ± 0.59	.03	<.001	1.5 ± 0.5	1.76 ± 0.48	<.001	1.92 ± 0.47	.01	<.001
Active energy expenditure (cal/min)	0.29 ± 0.21	0.34 ± 0.22	.005	0.44 ± 0.29	ns (.07)	<.001	0.23 ± 0.17	0.34 ± 0.22	.03	0.36 ± 0.25	.3	.01
Metabolic equivalent (1 kcal x kg ⁻¹ x h ⁻¹)	1.4 ± 0.2	1.8 ± 0.2	<.001	2.2 ± 0.2	<.001	<.001	1.3 ± 0.2	1.9 ± 0.3	<.001	2.1 ± 0.3	<.001	<.001
Total number of steps per day	4400 ± 2333	6847 ± 2653	<.001	9093 ± 3049	<.001	<.001	4091 ± 2128	5924 ± 2588	<.001	7291 ± 2914	<.001	<.001
Physical activity duration (min/d)	126 ± 87	189 ± 132	.001	200 ± 132	ns (.4)	.001	79 ± 78	109 ± 119	.001	129 ± 114	.1	<.001
Resting time (min/d)	564 ± 102	525 ± 109	.03	518 ± 95	ns (.6)	.01	559 ± 101	509 ± 97	.01	497 ± 86	.4	.003
Sleep duration (min/d)	370 ± 94	335 ± 77	.002	321 ± 81	ns (.4)	.02	402 ± 95	358 ± 78	.005	330 ± 73	.04	<.001

Abbreviation: ns, not significant.

Table 3. SF-36 Scores in KTx Recipients and in Patients With CKD Recorded at Baseline and After 12 Weeks of Physical Activity Program

	KTx Patients (n = 24)	CKD Patients (n = 15)	P Value (KTx patients vs CKD patients)
Physical functioning:			
Baseline	43.3 ± 2.4	40.1 ± 3.1	.3
Post-training	44.5 ± 1.2	42 ± 2.3	.006
P value (post-training vs baseline)	.01	.04	
Role limitation—physical:			
Baseline	19.8 ± 1	19.3 ± 1.8	.02
Post-training	20 ± 0	20 ± 0	
P value (post-training vs baseline)	.3	.2	
Social functioning:			
Baseline	3.2 ± 0.8	3.5 ± 0.9	.7
Post-training	3.5 ± 0.6	3.8 ± 0.9	.08
P value (post-training vs baseline)	.01	.09	
Mental health:			
Baseline	11.2 ± 2.4	10.8 ± 1.6	.09
Post-training	12.9 ± 1.5	11.7 ± 2.3	.1
P value (post-training vs baseline)	.008	.1	
Energy and vitality:			
Baseline	5.6 ± 2.1	3.8 ± 1.4	.1
Post-training	6.5 ± 1.4	3.7 ± 1.7	.07
P value (post-training vs baseline)	.1	.8	
Bodily pain:			
Baseline	3.3 ± 0.6	3.1 ± 0.7	.4
Post-training	3.5 ± 0.5	3.4 ± 0.5	.9
P value (post-training vs baseline)	.2	.3	
Role limitation—emotional:			
Baseline	15 ± 0	14.7 ± 1.3	
Post-training	15 ± 0	15 ± 0	
P value (post-training vs baseline)		.3	
General health perception:			
Baseline	1.7 ± 0.5	1.3 ± 0.6	.4
Post-training	1.8 ± 0.4	1.6 ± 0.5	.4
P value (post-training vs baseline)	.4	.09	
Physical component scale:			
Baseline	67.9 ± 2.9	64.4 ± 3.6	.4
Post-training	69.8 ± 1.3	67.3 ± 2.6	.003
P value (post-training vs baseline)	.004	.004	
Mental component scale:			
Baseline	35.1 ± 3.4	32.5 ± 2.6	.3
Post-training	37.9 ± 2.2	33.8 ± 2.9	.2
P value (post-training vs baseline)	.003	.1	

Abbreviations: CKD, chronic kidney disease; KTx, kidney transplant.

Self-assessed Physical Activity

Table 4 shows IPAQ scores. None of the patients in the study were employed at the time of the study, and therefore the items referring to job-related physical activity were left blank. At baseline, scores for leisure-time activities were significantly higher in KTx patients but remained unchanged in both groups during the training. Baseline scores for transportation activities and household activities did not differ between KTx and CKD patients. Both activities increased significantly within 12 weeks in KTx patients. Transportation activities increased significantly in CKD patients.

DISCUSSION

The results of our study indicate that the increased physical activity achieved through implementation of individualized structured exercise programs consisting of an initial short period of supervised exercises followed by short message service reminders and a series of self-assessments of daily activities may induce multiple beneficial effects on lifestyle, daily activity, sitting time, and quality of life in both KTx and non-dialyzed CKD patients. The largest effect was observed in the first weeks after the implementation of the program, when the training was supervised by a qualified physiotherapist.

Table 4. Physical Activity and Sitting Time Assessed With Long-Form International Physical Activity Questionnaire in KTx Recipients and in Patients with CKD at Baseline and After 4, 8, and 12 Weeks of Physical Activity Program

Professional activities	KTx Patients (n = 24)	CKD Patients (n = 15)	P value (KTx vs CKD)
	not applicable	not applicable	
Transportation activities (MET-min/wk):			
Baseline	2486 ± 1616	811 ± 1617	.9
After 4 weeks	3152 ± 1857	839 ± 2602	.1
After 8 weeks	4059 ± 2801	872 ± 2836	.9
After 12 weeks	5245 ± 4145	917 ± 3611	.6
P value (after 12 weeks vs baseline)	.001	.02	
Household activities (MET-min/wk):			
Baseline	2713 ± 2608	1976 ± 2273	.6
After 4 weeks	3646 ± 3497	2878 ± 2837	.4
After 8 weeks	4336 ± 4062	2335 ± 2343	.04
After 12 weeks	4559 ± 4116	3207 ± 4087	.9
P value (after 12 weeks vs baseline)	.0002	0.	
Leisure time activities (MET-min/wk):			
Baseline	1114 ± 968	562 ± 609	
After 4 weeks after 8 weeks	1250 ± 963	552 ± 577	<.0001
After 12 weeks	1295 ± 1121	735 ± 996	<.0002
P value (after 12 weeks vs baseline)	.1	0.	.7
Total low leisure time (MET-min/wk):			
Baseline	1926 ± 1427	1776 ± 1008	.2
After 4 weeks	3339 ± 1474	3463 ± 2293	.04
After 8 weeks	3737 ± 1568	3214 ± 1297	.5
After 12 weeks	3863 ± 1602	3828 ± 2533	.03
P value (after 12 weeks vs baseline)	<.0001	.001	
Total moderate leisure time (MET-min/wk):			
Baseline	3448 ± 2346	3011 ± 1750	.2
After 4 weeks	4180 ± 2642	3486 ± 2104	.3
After 8 weeks	5023 ± 3136	5023 ± 3136	.2
After 12 weeks	5580 ± 4827	5580 ± 4827	.2
P value (after 12 weeks vs baseline)	.01	.02	
Total vigorous leisure time (MET-min/wk):			
Baseline	890 ± 1691	555 ± 1024	.06
After 4 weeks	1260 ± 2351	800 ± 1314	.03
After 8 weeks	1793 ± 2971	775 ± 1119	.005
After 12 weeks	3000 ± 4612	18990 ± 3052	.1
P value (after 12 weeks vs baseline)	.05	.07	

Abbreviations: CKD, chronic kidney disease; KTx, kidney transplant; MET, metabolic equivalent of task.

Most studies that have assessed physical activity in patients with CKD were carried out in hemodialysis patients. The studies in hemodialysis patients found that baseline physical activity levels were significantly lower in that population compared to healthy sedentary patients [19,20]. The results of intervention studies have indicated that all types of exercise training regardless of their intensity, duration, and supervision have led to a significant improvement in physical capacity of the patients; however, the long-term effects were uncertain. The activity models improving physical activity in CKD patients included repeated exercises involving large groups of muscles such as with cycling, walking, and jogging [21]. Based on those findings, similar types of exercise training were selected for our study.

We assumed that such a complex program may be better suited for KTx recipients, who often, despite a successful transplantation, remain inactive and nonemployed and

lead a sedentary lifestyle [22]. The KTx patients in our study had a significantly longer period of activity and greater energy expenditure at baseline than the CKD patients had. The 12-week exercise training induced a beneficial effect on all parameters of physical activity in both groups of patients.

The patients with CKD have a slower gait, which constitutes a strong prognostic factor of mortality [23]. In our study, the baseline total energy expenditure was lower in CKD and KTx patients in comparison to the general population [24]. After the training program, the total energy expenditure significantly increased in both groups of patients; however, it did not reach the average level of total energy expenditure observed in the general population.

The effect of physical activity on quality of life was assessed in our study with the SF-36 questionnaire. This tool has been previously used and validated in both CKD

patients and patients after KTx [25–27]. We found that the increased physical activity led to a significant improvement in quality of life in both the physical and mental sphere in KTx patients but only in the physical sphere in CKD patients. These results were concordant with the results of the study of den Ham et al [27], who found that the quality of life was improved in all aspects in KTx patients, as well as in chronic hemodialysis patients. However, not unexpectedly, the most significant improvement was observed in the physical sphere. The previous studies in KTx recipients [27] and hemodialysis patients [25,26] revealed that exercise training significantly improved quality of life associated with health, particularly with physical functioning. Also the study of Mazzoni et al [28] revealed that regular sporting activities significantly improve different dimensions of health-related quality of life among KTx recipients.

Self-reporting is a popular method for assessing physical activity despite numerous shortcomings of the questionnaires, including a recall bias and inaccurate interpretation of the questions. The long form of the IPAQ was completed by the patients 4 times during our study, and we were able to notice a regular improvement of self-reporting of physical activity in both groups of patients. Unfortunately, with repeated surveys, there is the possibility of patients learning the answers, which can be recognized as a limitation of the results of the IPAQ.

Our study was not randomized and blinded, which is a common limitation of clinical trials with interventions that require active patient involvement. The main limitations of our study were the small group of patients and the short time of exercise training. Additionally, the study comprised only the clinically stable patients after KTx and the patients with CKD without any serious debilitating comorbidities, since the subjects with a history of cardiovascular incidents and diabetes were excluded. Therefore, the results of the study cannot be extended to the whole KTx population. However such a bias occurs in most studies assessing the effect of exercise training in patients with CKD. The only exception was the Renal Exercise Demonstration Project [26], which included a large group of hemodialysis patients without any age and comorbidity limitations. However, in that study, approximately 50% of the patients did not complete the physical functioning tests [26]. Although the exercises improved physical functioning of these patients, the improvement was smaller than in the remaining patients.

In summary, our study has emphasized a clinical importance of individualized physical training in both KTx and CKD patients. Therefore, we contend that exercise training should be considered as a part of routine treatment in these populations. It is yet to be determined if the beneficial effects of a short-term, intensive physical activity program on physical outcomes and quality of life will persist after the end of the training program and whether such a program could induce long-lasting changes in lifestyle directed toward regular physical activity.

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REFERENCES

- [1] Painter P, Roshanravan B. The association of physical activity and physical function with clinical outcomes in adults with chronic kidney disease. *Curr Opin Nephrol Hypertens* 2013;22:615–23.
- [2] Roe P, Wolfe M, Joffe M, Rosas SE. Inflammation, coronary artery calcification and cardiovascular events in incident renal transplant recipients. *Atherosclerosis* 2010;212:589–94.
- [3] O'Hare AM, Tawney K, Bacchetti P, Johansen KJ. Decreased survival among sedentary patients undergoing dialysis: results from the Dialysis Morbidity and Mortality Study Wave 2. *Am J Kidney Dis* 2003;41:447–54.
- [4] Tawney KW, Tawney PJ, Kovach J. Disablement and rehabilitation in end-stage renal disease. *Semin Dial* 2003;16:447–52.
- [5] Johansen KL. Exercise and chronic kidney disease: current recommendations. *Sports Med* 2005;35:485–99.
- [6] Zelle DM, Corpeleijn E, Stolk RP, et al. Low physical activity and risk of cardiovascular and all-cause mortality in renal transplant recipients. *Clin J Am Soc Nephrol* 2011;6:898–905.
- [7] Rambod M, Shabani M, Shokrpour N, Rafii F, Mohammadalliha J. Quality of life of hemodialysis and renal transplantation patients. *Health Care Manag (Frederick)* 2011;30:23–8.
- [8] Buzgova R, Smotkova S. Comparing of life in dialysis patients and patients after kidney transplantation: a questionnaire survey. *Cas Lek Cesk* 2013;152:233–9.
- [9] Beddhu S, Baird BC, Zitterkoph J, Neilsen J, Greene T. Physical activity and mortality in chronic kidney disease (NHANES III). *Clin J Am Soc Nephrol* 2009;4:1901–6.
- [10] Nowicki M, Murlikiewicz K, Jagodzińska M. Pedometers as a means to increase spontaneous physical activity in chronic hemodialysis patients. *J Nephrol* 2010;23:297–305.
- [11] Esteghamati A, Khalilzadeh O, Rashidi A, et al. Association between physical activity and insulin resistance in Iranian adults: National Surveillance of Risk Factors of Non-Communicable Diseases (SuRFNCD–2007). *Prev Med* 2009;49:402–6.
- [12] Ford ES. Does exercise reduce inflammation? Physical activity and C-reactive protein among U.S. adults. *Epidemiology* 2002;13:561–8.
- [13] Laukkanen JA, Sudhir K, Salonen JT. Cardiorespiratory fitness and physical activity as risk predictors of future atherosclerotic cardiovascular diseases. *Curr Atheroscler Rep* 2002;4:468–76.
- [14] Masajtis-Zagajewska A, Muras K, Nowicki M. Effects of a structured physical activity program on habitual physical activity and body composition in patients with chronic kidney disease and in kidney transplant recipients. *Exp Clin Transplant* 2019;17:155–64.
- [15] Nielsen 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. *Nephrol Dial Transplant* 2001;16:134–40.
- [16] DiLoreto C, Fanelli C, Lucidi P, et al. Make your diabetic patients walk. Long-term impact of different amounts of physical activity on type 2 diabetes. *Diabetes Care* 2005;28:1295–302.
- [17] Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35:1381–95.
- [18] Ainsworth BE, Haskell WL, Whitt M, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000;32:498–504.
- [19] Johannes KL, Chertow GM, Ng AV, et al. Physical activity levels in patients on hemodialysis and healthy sedentary controls. *Kidney Int* 2000;57:2564–70.

- [20] Majchrzak KM, Pupim LB, Chen K, et al. Physical activity patterns in chronic hemodialysis patients: comparison of dialysis and nondialysis days. *J Ren Nutr* 2005;15:217–24.
- [21] Heiwe S, Jacobson SH. Exercise training for adults with chronic kidney disease. *Cochrane Database Syst Rev* 2011;10:CD003236.
- [22] Moons P, Vanrenterghem Y, van Hooff JP, et al. Health-related quality of life and symptom experience in tacrolimus-based regimens after renal transplantation: a multicentre study. *Transpl Int* 2003;16:653–64.
- [23] Roshanravan B, Robinson-Cohen C, Patel KV, et al. Association between physical performance and all-cause mortality in CKD. *J Am Soc Nephrol* 2013;24:822–30.
- [24] Passmore R, Durnin JVGA. Human energy expenditure. *Physiol Rev* 1955;35:801–40.
- [25] Levendoglu F, Altintepe L, Okudan N, et al. A twelve week exercise program improves the psychological status, quality of life and work capacity in hemodialysis patients. *J Nephrol* 2004;17:826–32.
- [26] Painter P, Carlson L, Carey S, Paul SM, Myll J. Physical functioning and health-related quality-of-life changes with exercise training in hemodialysis patients. *Am J Kidney Dis* 2000;35:482–92.
- [27] Van den Ham EC, Kooman JP, Schols AM, et al. The functional, metabolic and anabolic responses to exercise training in renal transplant and hemodialysis. *Transplantation* 2007;83:1059–68.
- [28] Mazzoni D, Cicognani E, Mosconi G, et al. Sport activity and health-related quality of life after kidney transplantation. *Transplant Proc* 2014;46:2231–4.