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Original Article

Relationship between Changes in Physical Activity and Changes in Health-related Quality of Life in Patients on Chronic Hemodialysis with 1-Year Follow-up

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In a longitudinal study, we examined the link between changes in physical activity and changes in health-related quality of life (HRQOL) in patients on chronic hemodialysis. Seventy-one patients (43 males, 28 females; aged 70.9 ± 10.6 years) on chronic hemodialysis in September 2013 were enrolled. The data of the 43 patients whose complete measurements were taken again in September 2014 were used for the longitudinal analysis. Clinical parameters including age, height, dry weight, duration of hemodialysis, blood pressure (BP), blood triglyceride and HDL cholesterol levels, physical activity, and HRQOL were evaluated. Physical activity was measured by a tri-accelerometer, and HRQOL was evaluated by the EuroQol questionnaire (EQ-5D). In the first cross-sectional analysis, EQ-5D scores were significantly correlated with daily step counts (steps per day) on all days and non-hemodialysis days. In the second longitudinal analysis, in the women, changes in EQ-5D scores were positively correlated with changes in daily step counts on all days. In all patients, changes in EQ-5D were weakly and negatively correlated with changes in physical activity (1-3 METs: min per day) on hemodialysis days. Promoting daily physical activity may improve the HRQOL in patients on chronic hemodialysis, especially in women.

Key words: hemodialysis, health related quality of life (HRQOL), physical activity

The number of patients on chronic dialysis is increasing and has become a public health challenge in Japan. For example, according to a report by the Japanese Society for Dialysis Therapy (http://docs.jsdt.or.jp/overview/pdf2014/p003.pdf [in Japanese]), accessed in March 2015, 314, 180 patients in Japan were undergoing chronic dialysis. It is well known that lifestyle modifications in terms of physical activity, diet, and mental health are important for patients on chronic hemodialysis [1]. In a cross-sectional study, we observed that an individual's health-related quality of life (HRQOL) is closely associated with his or her physical activity over 4 metabolic equivalents of task (METs) on non-hemodialysis therapy days [2]. HRQOL was also linked to psychological distress in a longitudinal study [3]. Taken together, these findings indicate that increasing physical activity and improving psychological distress might enhance the HRQOL in patients on chronic

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hemodialysis. However, the relationship between the changes in physical activity and the changes in HRQOL in a longitudinal analysis remained to be investigated.

In the present study therefore, we evaluated the effects of changes in physical activity on changes in HRQOL in patients on chronic hemodialysis with a 1-year follow-up.

Subjects and Methods

Subjects. We enrolled a total of 71 patients (43 males, 28 females) on chronic hemodialysis aged 70.9 ± 10.6 years who met the following criteria: (1) they were outpatients on chronic hemodialysis at Innoshima General Hospital, Onomichi, Japan, in September 2013; (2) they underwent measurements of their height, dry weight, blood pressure (BP), blood levels (*i.e.*, triglyceride [mg/dL] and high-density lipoprotein (HDL) cholesterol [mg/dL]), physical activity, and HRQOL; and (3) they provided written informed consent. The patients' characteristics are summarized in Table 1. Among the 71 patients, we used the data of 43 patients whose complete measurements were taken again in September 2014 in a longitudinal analysis.

Ethical approval to conduct this study was obtained from the Ethical Committee of Innoshima General Hospital, Onomichi, Japan (H25-2-27 and H26-1-23).

Clinical parameters. As described [2,3], we evaluated each patient's age, height (cm), duration of hemodialysis (months), BP (mmHg), HRQOL, and triglyceride and HDL cholesterol levels. Blood samples were collected after the patient ate a meal, during chronic hemodialysis being conducted at 2-day intervals. The patient's HRQOL was evaluated with the EuroQol questionnaire (EQ-5D) [4]. Physical activity was measured by a tri-accelerometer (Active Style Pro HJA-350IT, Omron Healthcare, Kyoto, Japan) with the following specifications: 74 × 46 × 34 mm, 60 g including batteries [5]. The tri-accelerometer was used to measure not only physical activity but also sedentary time. Patients wore the tri-accelerometer on the left side of the waist throughout the day from the time they woke up in the morning until they went to bed at night, except while showering and bathing. The patients were requested to wear the tri-accelerometer for 14 days. We used the data from > 10 h (600 min) of wearing time in a day [6-8]. The data measured by the tri-accelerometer were calculated and stratified by 3 different intensity levels as follows: 1-3 METs, 3-4 METs, and > 4 METs, according to the definition provided in the Exercise and Physical Activity Guide for Health Promotion 2006 (http://www.nibiohn.go.jp/eiken/programs/pdf/epar2006.pdf [in Japanese]), accessed on Feb. 14, 2016.

The K6 score. The Kessler Screening Scale for Psychological Distress (K6) score was used as an index of psychological distress [9,10]. The K6 questionnaire is composed of 6 questions as follows: "Over the last month, how often did you feel: (1) nervous, (2) hopeless, (3) restless or fidgety, (4) so sad that nothing could cheer you up, (5) that everything was an effort, (6) worthless?" The patients were asked to respond by selecting from the following: "all of the time" (4 points), "most of the time" (3 points), "some of the time" (2 points), "a little of the time" (1 point), and "none of the time" (0 points). As suggested by Kessler *et al.* [11], we classified the patients who had scores > 13 points as a depressive state.

Statistical analysis. Data are expressed as mean ± SD. We analyzed the differences between 2 groups by using the unpaired *t*-test and paired *t*-test. A simple correlation analysis was used for continuous variables, where *p*-values < 0.05 were considered significant.

Results

The clinical profiles of the enrolled patients on chronic hemodialysis are summarized in Table 1. The EQ-5D scores of all patients were 0.720 ± 0.224. The total physical activity was 0.89 ± 0.86 METs•h/day in all patients on all days. The results of our analysis of the relationships between the EQ-5D scores and the various clinical parameters at baseline are shown in Table 2. In our first analysis of the entire patient population, the EQ-5D scores were positively and significantly correlated with the daily step counts on all and non-hemodialysis days in all patients.

In the men, the EQ-5D scores were positively correlated with the daily step counts (all days and non-hemodialysis days) and the daily step hours (non-hemodialysis days), and the EQ-5D scores were negatively correlated with the K6 scores.

In the women, the EQ-5D scores were positively

Table 1 Clinical characteristics of patients on chronic hemodialysis

	Total			Men			Women		
	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	Minimum	Maximum
Number of subjects	71			43			28		
Age (years)	70.9 ± 10.6	44	89	71.7 ± 10.8	44	89	69.6 ± 10.2	49	87
Height (cm)	155.9 ± 10.0	133.6	184.5	161.2 ± 7.7	138.0	184.5	147.9 ± 7.4	133.6	163.2
Body weight (dry weight) (kg)	54.8 ± 12.8	35.3	119.0	58.7 ± 13.2	39.7	119.0	48.9 ± 9.6	35.3	73.6
BMI (kg/m^2)	22.4 ± 3.5	16.4	35.0	22.4 ± 3.5	16.4	35.0	22.3 ± 3.6	17.0	31.0
Body fat (%)	31.6 ± 9.9	6.7	53.1	29.6 ± 10.1	6.7	52.4	34.7 ± 8.8	19.2	53.1
Duration of hemodialysis (months)	95.2 ± 97.0	4	378	81.8 ± 86.7	4	354	115.8 ± 109.4	5	378
K6 score	4.6 ± 5.0	0	22	4.1 ± 4.4	0	16	5.3 ± 5.8	0	22
EQ-5D score	0.720 ± 0.224	−0.062	1.000	0.760 ± 0.229	−0.062	1.000	0.658 ± 0.204	0.195	1.000
SBP (mmHg)	138.6 ± 20.3	98.0	200.0	136.8 ± 17.0	98.0	182.0	141.4 ± 24.5	101.0	200.0
DBP (mmHg)	75.8 ± 11.9	46.0	108.0	74.0 ± 10.1	46.0	90.0	78.5 ± 14.0	48.0	108.0
Triglyceride (mg/dL)	113.0 ± 80.2	29.0	434.0	113.2 ± 86.3	29.0	434.0	112.6 ± 71.2	52.0	403.0
HDL cholesterol (mg/dL)	56.0 ± 18.1	19.1	108.7	52.1 ± 17.0	19.1	101.0	62.0 ± 18.5	28.4	108.7
Blood glucose (mg/dL)	129.2 ± 37.9	75.0	267.0	125.8 ± 26.6	75.0	208.0	134.4 ± 50.7	81.0	267.0
Albumin (g/mL)	3.7 ± 0.3	2.9	4.2	3.7 ± 0.3	2.9	4.2	3.7 ± 0.3	2.9	4.2
All days									
Locomotive physical activity (METs·h/day)	0.43 ± 0.55	0.00	2.39	0.45 ± 0.59	0.00	2.39	0.40 ± 0.49	0.00	2.11
Non-locomotive physical activity (METs·h/day)	0.46 ± 0.55	0.01	3.24	0.44 ± 0.62	0.01	3.24	0.50 ± 0.43	0.05	1.98
Total physical activity (METs·h/day)	0.89 ± 0.86	0.01	3.84	0.88 ± 0.96	0.01	3.84	0.89 ± 0.70	0.05	2.62
Daily step count (steps per day)	2,445.7 ± 2,018.3	15.0	10,357.1	2,315.4 ± 1,947.4	15.0	8,410.4	2,645.9 ± 2,178.1	24.9	10,357.1
Daily step hours (minutes/day)	42.1 ± 27.6	0.3	113.3	41.9 ± 27.6	0.3	99.1	42.3 ± 28.2	1.0	113.3
Physical activity (1-3 METs)(minutes/day)	627.5 ± 260.6	126.7	1,221.6	538.7 ± 255.4	126.7	1,192.7	764.0 ± 206.6	364.3	1,221.6
Physical activity (3-4 METs)(minutes/day)	14.4 ± 13.6	0.1	54.6	14.1 ± 15.0	0.1	54.6	14.7 ± 11.3	0.6	42.4
Physical activity (＞4 METs)(minutes/day)	1.4 ± 2.9	0.0	18.0	1.5 ± 3.3	0.0	18.0	1.3 ± 2.1	0.0	8.9
Hemodialysis days									
Locomotive physical activity (METs·h/day)	0.37 ± 0.52	0.00	2.24	0.39 ± 0.56	0.00	2.24	0.35 ± 0.45	0.00	2.07
Non-locomotive physical activity (METs·h/day)	0.47 ± 0.52	0.00	2.94	0.43 ± 0.57	0.00	2.94	0.54 ± 0.44	0.09	1.93
Total physical activity (METs·h/day)	0.84 ± 0.81	0.00	3.43	0.82 ± 0.89	0.00	3.43	0.89 ± 0.66	0.09	2.39
Daily step count (steps per day)	2,370.6 ± 2,044.6	10.7	10,241.3	2,132.5 ± 1,877.8	10.7	7,474.3	2,736.3 ± 2,263.7	17.0	10,241.3
Daily step hours (minutes/day)	39.8 ± 29.2	0.3	127.7	39.0 ± 29.6	0.3	127.7	41.0 ± 29.0	1.7	112.3
Physical activity (1-3 METs)(minutes/day)	624.1 ± 291.9	63.0	1,271.7	525.5 ± 297.5	63.0	1,271.7	775.5 ± 209.6	319.0	1,168.3
Physical activity (3-4 METs)(minutes/day)	13.9 ± 13.0	0.0	54.7	13.4 ± 14.4	0.0	54.7	14.7 ± 10.8	1.0	36.0
Physical activity (＞4 METs)(minutes/day)	1.2 ± 2.4	0.0	13.3	1.2 ± 2.4	0.0	13.3	1.3 ± 2.3	0.0	11.0
Non-hemodialysis days									
Locomotive physical activity (METs·h/day)	0.47 ± 0.63	0.00	2.50	0.49 ± 0.67	0.00	2.50	0.43 ± 0.59	0.00	2.14
Non-locomotive physical activity (METs·h/day)	0.45 ± 0.61	0.01	3.45	0.44 ± 0.70	0.01	3.45	0.46 ± 0.45	0.02	2.02
Total physical activity (METs·h/day)	0.92 ± 0.98	0.01	4.15	0.94 ± 1.08	0.01	4.15	0.90 ± 0.82	0.02	3.05
Daily step count (steps per day)	2,502.1 ± 2,236.5	18.0	10,444.0	2,452.5 ± 2,221.6	18.3	10,357.3	2,578.1 ± 2,297.9	18.0	10,444.0
Daily step hours (minutes/day)	43.8 ± 30.8	0.3	120.8	44.1 ± 30.9	0.3	120.8	43.3 ± 31.3	0.3	115.0
Physical activity (1-3 METs)(minutes/day)	630.1 ± 260.8	101.3	1,288.8	548.5 ± 245.3	101.3	1,175.3	755.4 ± 236.1	349.8	1,288.8
Physical activity (3-4 METs)(minutes/day)	14.7 ± 15.4	0.3	63.0	14.6 ± 16.7	0.3	63.0	14.7 ± 13.4	0.3	47.3
Physical activity (＞4 METs)(minutes/day)	1.6 ± 3.5	0.0	21.5	1.8 ± 4.2	0.0	21.5	1.3 ± 2.2	0.0	7.3

BMI, body mass index (kg/m^2); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg).

correlated with locomotive the physical activity (all days, hemodialysis days, and non-hemodialysis days), total physical activity (all days, hemodialysis days, and non-hemodialysis days), daily step counts (all days, hemodialysis days, and non-hemodialysis days), daily step hours (hemodialysis days) and physical activity (3–4 METs) (all days, hemodialysis days, and non-hemodialysis days) (Table 2).

We compared the clinical parameters at baseline between the patients with (n = 43) and without (n = 28) a 1-year follow-up (Table 3). Among the 28 patients who could not be followed up for a year, 3 died, the physical activity of 18 was not measured, and the physical activity data were incomplete for 7. The following parameters were significantly higher in the patients with follow-up compared to the patients without follow-up: EQ-5D scores, SBP, locomotive physical activity (all days, hemodialysis days, and non-he-

Table 2 Simple correlation analysis between EQ-5D scores and clinical parameters

	Total (n = 71)		Men (n = 43)		Women (n = 28)	
	r	*p*	*r*	*p*	*r*	*p*
Age (years)	−0.238	0.045	−0.278	0.071	−0.247	0.205
BMI (kg/m^2)	−0.089	0.463	−0.254	0.100	0.170	0.387
Body fat (%)	−0.220	0.071	−0.352	0.024	0.184	0.360
Duration of hemodialysis (months)	−0.151	0.208	−0.148	0.344	−0.080	0.686
K6 score	−0.367	0.002	−0.423	0.005	−0.272	0.161
SBP (mmHg)	0.123	0.305	0.311	0.042	0.007	0.973
DBP (mmHg)	−0.127	0.291	−0.026	0.868	−0.208	0.288
Triglyceride (mg/dL)	−0.021	0.863	−0.073	0.642	0.085	0.666
HDL cholesterol (mg/dL)	0.091	0.448	0.374	0.013	−0.178	0.366
Blood glucose (mg/dL)	−0.133	0.267	−0.146	0.352	−0.097	0.623
Albumin (g/mL)	0.320	0.006	0.297	0.053	0.352	0.067
All days						
Locomotive physical activity (METs·h/day)	0.371	<0.001	0.275	0.074	0.572	<0.001
Non-locomotive physical activity (METs·h/day)	0.216	0.071	0.218	0.160	0.277	0.154
Total physical activity (METs·h/day)	0.374	<0.001	0.310	0.043	0.571	0.002
Daily step count (steps per day)	0.446	<0.001	0.407	0.007	0.596	<0.001
Daily step hours (minutes/day)	0.377	<0.001	0.383	0.011	0.399	0.035
Physical activity (1–3 METs)(minutes/day)	−0.229	0.055	−0.244	0.114	0.049	0.806
Physical activity (3–4 METs)(minutes/day)	0.363	0.002	0.303	0.048	0.555	0.002
Physical activity (> 4 METs)(minutes/day)	0.250	0.036	0.204	0.190	0.387	0.042
Hemodialysis days						
Locomotive physical activity (METs·h/day)	0.342	0.004	0.223	0.151	0.605	<0.001
Non-locomotive physical activity (METs·h/day)	0.160	0.183	0.159	0.309	0.254	0.192
Total physical activity (METs·h/day)	0.321	0.006	0.239	0.122	0.581	<0.001
Daily step count (steps per day)	0.379	<0.001	0.313	0.041	0.601	<0.001
Daily step hours (minutes/day)	0.303	0.010	0.267	0.084	0.410	0.030
Physical activity (1–3 METs)(minutes/day)	−0.247	0.038	−0.275	0.075	0.074	0.707
Physical activity (3–4 METs)(minutes/day)	0.297	0.012	0.212	0.172	0.564	0.002
Physical activity (> 4 METs)(minutes/day)	0.265	0.026	0.248	0.109	0.335	0.081
Non-hemodialysis days						
Locomotive physical activity (METs·h/day)	0.356	0.002	0.287	0.062	0.488	0.008
Non-locomotive physical activity (METs·h/day)	0.239	0.045	0.242	0.118	0.276	0.155
Total physical activity (METs·h/day)	0.380	<0.001	0.335	0.028	0.507	0.006
Daily step count (steps per day)	0.450	<0.001	0.425	0.004	0.545	0.003
Daily step hours (minutes/day)	0.376	<0.001	0.408	0.007	0.343	0.074
Physical activity (1–3 METs)(minutes/day)	−0.192	0.108	−0.195	0.210	0.025	0.900
Physical activity (3–4 METs)(minutes/day)	0.373	<0.001	0.340	0.026	0.480	0.010
Physical activity (> 4 METs)(minutes/day)	0.226	0.058	0.177	0.255	0.379	0.047

BMI, body mass index (kg/m^2); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg).
Bold values are statistically significant ($p < 0.05$).

modialysis days), total physical activity (all days and hemodialysis days), daily step counts (all days, hemodialysis days, and non-hemodialysis days), daily step hours (all days, hemodialysis days, and non-hemodialysis days), and physical activity (3–4 METs) (all days, hemodialysis days, and non-hemodialysis days). Thus, the patients with follow-up were observed to be more active than the patients without follow-up.

As a second analysis, we evaluated the changes in the parameters the patients on chronic hemodialysis

Table 3 Comparison of clinical parameters between patients on chronic hemodialysis with and without follow-up

	Follow-up (+) (n = 43) Mean ± SD	Follow-up (−) (n = 28) Mean ± SD	*p*
Men/Women	26/17	17/11	
Age (years)	69.1 ± 10.8	73.7 ± 9.8	0.071
Height (cm)	157.3 ± 9.2	153.9 ± 10.9	0.162
Body weight (dry weight) (kg)	54.7 ± 11.2	55.0 ± 15.1	0.930
BMI (kg/m^2)	22.0 ± 3.3	23.0 ± 3.8	0.246
Body fat (%)	30.2 ± 9.3	34.2 ± 10.5	0.107
Duration of hemodialysis (months)	93.9 ± 85.2	97.3 ± 114.4	0.889
K6 score	4.2 ± 5.1	5.1 ± 4.8	0.443
EQ-5D score	0.789 ± 0.175	0.614 ± 0.251	<0.001
SBP (mmHg)	140.7 ± 21.5	135.5 ± 18.0	0.289
DBP (mmHg)	78.5 ± 10.1	71.5 ± 13.3	0.022
Triglyceride (mg/dL)	104.0 ± 79.5	126.7 ± 80.6	0.246
HDL cholesterol (mg/dL)	56.4 ± 15.4	55.5 ± 21.9	0.831
Blood glucose (mg/dL)	127.1 ± 37.7	132.4 ± 38.6	0.570
Albumin (g/mL)	3.7 ± 0.3	3.6 ± 0.3	0.308
All days			
Locomotive physical activity (METs·h/day)	0.54 ± 0.55	0.25 ± 0.51	0.028
Non-locomotive physical activity (METs·h/day)	0.52 ± 0.56	0.37 ± 0.55	0.280
Total physical activity (METs·h/day)	1.06 ± 0.88	0.62 ± 0.79	0.036
Daily step count (steps per day)	3,169.4 ± 2,024.2	1,334.4 ± 1,491.2	<0.001
Daily step hours (minutes/day)	51.1 ± 26.0	28.1 ± 24.4	<0.001
Physical activity (1–3 METs)(minutes/day)	669.5 ± 229.8	563.1 ± 294.6	0.093
Physical activity (3–4 METs)(minutes/day)	17.7 ± 13.8	9.3 ± 11.8	0.010
Physical activity (> 4 METs)(minutes/day)	1.4 ± 2.4	1.5 ± 3.6	0.874
Hemodialysis days			
Locomotive physical activity (METs·h/day)	0.47 ± 0.54	0.22 ± 0.44	0.040
Non-locomotive physical activity (METs·h/day)	0.54 ± 0.54	0.37 ± 0.47	0.181
Total physical activity (METs·h/day)	1.01 ± 0.85	0.59 ± 0.67	0.029
Daily step count (steps per day)	3,039.0 ± 2,031.3	1,344.3 ± 1,617.5	<0.001
Daily step hours (minutes/day)	48.7 ± 30.1	26.0 ± 21.6	<0.001
Physical activity (1–3 METs)(minutes/day)	667.3 ± 277.0	557.8 ± 306.5	0.123
Physical activity (3–4 METs)(minutes/day)	16.9 ± 13.8	9.3 ± 10.4	0.010
Physical activity (> 4 METs)(minutes/day)	1.3 ± 2.3	1.1 ± 2.5	0.764
Non-hemodialysis days			
Locomotive physical activity (METs·h/day)	0.60 ± 0.63	0.27 ± 0.60	0.036
Non-locomotive physical activity (METs·h/day)	0.50 ± 0.62	0.37 ± 0.61	0.393
Total physical activity (METs·h/day)	1.10 ± 0.99	0.65 ± 0.92	0.058
Daily step count (steps per day)	3,267.2 ± 2,295.0	1,327.1 ± 1,552.6	<0.001
Daily step hours (minutes/day)	52.9 ± 28.8	29.7 ± 28.8	<0.001
Physical activity (1–3 METs)(minutes/day)	671.2 ± 222.6	567.0 ± 303.9	0.100
Physical activity (3–4 METs)(minutes/day)	18.2 ± 15.7	9.2 ± 13.3	0.015
Physical activity (> 4 METs)(minutes/day)	1.5 ± 2.6	1.8 ± 4.7	0.705

BMI, body mass index (kg/m^2); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg).
Bold values are statistically significant ($p < 0.05$).

after 1 year (n＝43) (Table 4). Albumin was significantly increased and physical activity (1–3 METs) on hemodialysis days was significantly decreased at the 1–year follow-up.

We also evaluated the changes in EQ–5D scores and the changes in clinical parameters at the 1–year follow-up (Table 5). Changes in EQ–5D scores were significantly and positively correlated with changes in triglyceride levels in the men (n＝26). In addition, in the women (n＝17), changes in EQ–5D scores were

Table 4 Changes in clinical parameters in patients on chronic hemodialysis with 1–year follow-up (n＝43)

	Baseline Mean ± SD	Follow-up Mean ± SD	*p*
Men/Women	26/17		
Age (years)	69.1 ± 10.8		
Height (cm)	157.3 ± 9.2		
Duration of hemodialysis (months)	93.9 ± 85.2		
Body weight (dry weight) (kg)	54.7 ± 11.2	53.0 ± 11.2	0.229
BMI (kg/m^2)	22.0 ± 3.3	21.4 ± 4.1	0.248
Body fat (%)	30.2 ± 9.3	31.5 ± 9.9	0.148
K6 score	4.2 ± 5.1	4.3 ± 4.8	0.912
EQ–5D score	0.789 ± 0.175	0.790 ± 0.181	0.943
SBP (mmHg)	140.7 ± 21.5	137.2 ± 20.2	0.171
DBP (mmHg)	78.5 ± 10.1	75.9 ± 10.9	0.381
Triglyceride (mg/dL)	104.0 ± 79.5	97.5 ± 62.1	0.445
HDL cholesterol (mg/dL)	56.4 ± 15.4	57.7 ± 13.7	0.479
Blood glucose (mg/dL)	127.1 ± 37.7	131.3 ± 43.3	0.424
Albumin (g/mL)	3.7 ± 0.3	4.0 ± 0.3	**<0.001**
All days			
Locomotive physical activity (METs･h/day)	0.54 ± 0.55	0.57 ± 0.64	0.735
Non-locomotive physical activity (METs･h/day)	0.52 ± 0.56	0.54 ± 0.59	0.623
Total physical activity (METs･h/day)	1.06 ± 0.88	1.11 ± 0.99	0.609
Daily step count (steps per day)	3,169.4 ± 2,024.2	2,901.6 ± 1,752.9	0.239
Daily step hours (minutes/day)	51.1 ± 26.0	49.1 ± 26.8	0.479
Physical activity (1–3 METs)(minutes/day)	669.5 ± 229.8	645.6 ± 238.9	0.423
Physical activity (3–4 METs)(minutes/day)	17.7 ± 13.8	17.5 ± 14.9	0.912
Physical activity (＞4 METs)(minutes/day)	1.4 ± 2.4	2.0 ± 3.8	0.208
Hemodialysis days			
Locomotive physical activity (METs･h/day)	0.47 ± 0.54	0.55 ± 0.56	0.305
Non-locomotive physical activity (METs･h/day)	0.54 ± 0.54	0.49 ± 0.55	0.362
Total physical activity (METs･h/day)	1.01 ± 0.85	1.04 ± 0.87	0.779
Daily step count (steps per day)	3,039.0 ± 2,031.3	2,610.8 ± 1,431.1	0.122
Daily step hours (minutes/day)	48.7 ± 30.1	44.4 ± 24.4	0.257
Physical activity (1–3 METs)(minutes/day)	667.3 ± 277.0	589.4 ± 268.2	**0.037**
Physical activity (3–4 METs)(minutes/day)	16.9 ± 13.8	16.2 ± 13.1	0.649
Physical activity (＞4 METs)(minutes/day)	1.3 ± 2.3	2.0 ± 2.7	0.094
Non-hemodialysis days			
Locomotive physical activity (METs･h/day)	0.60 ± 0.63	0.58 ± 0.83	0.887
Non-locomotive physical activity (METs･h/day)	0.50 ± 0.62	0.59 ± 0.70	0.277
Total physical activity (METs･h/day)	1.10 ± 0.99	1.17 ± 1.21	0.607
Daily step count (steps per day)	3,267.2 ± 2,295.0	3,122.1 ± 2,288.4	0.611
Daily step hours (minutes/day)	52.9 ± 28.8	52.7 ± 32.9	0.957
Physical activity (1–3 METs)(minutes/day)	671.2 ± 222.6	686.0 ± 237.8	0.665
Physical activity (3–4 METs)(minutes/day)	18.2 ± 15.7	18.5 ± 17.9	0.866
Physical activity (＞4 METs)(minutes/day)	1.5 ± 2.6	2.0 ± 5.7	0.471

BMI, body mass index (kg/m^2); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg).
Bold values are statistically significant ($p < 0.05$).

significantly and positively correlated with changes in daily step counts on all days ($r = 0.499$, $p = 0.041$). Changes in physical activity (1–3 METs: min/day) were weakly and negatively correlated with changes in EQ-5D scores in all patients ($r = -0.337$, $p = 0.027$).

Discussion

The main finding of this study was that physical activity, especially daily step counts, was positively correlated with the HRQOL in female patients on chronic hemodialysis in the longitudinal study.

We also observed that in general, the level of physical activity in the patients on chronic hemodialysis was lower than that in the average person. Using the Global Physical Activity Questionnaire (GPAQ), Wong *et al.* found that none of their hemodialysis patients had high physical activity levels [12].

Table 5 Simple correlation analysis between changes in EQ5D scores and changes in clinical parameters at 1-year follow-up

	Total (n = 43)		Men (n = 26)		Women (n = 17)	
	r	*p*	*r*	*p*	*r*	*p*
Δ Body weight (kg)	0.028	0.857	0.088	0.669	−0.262	0.310
Δ BMI (kg/m^2)	0.020	0.898	0.074	0.718	−0.198	0.447
Δ Body fat (%)	0.220	0.155	0.286	0.156	−0.039	0.881
Δ EQ-5D score	−0.197	0.205	−0.363	0.069	0.005	0.985
Δ SBP (mmHg)	0.056	0.723	0.209	0.305	−0.268	0.299
Δ DBP (mmHg)	−0.014	0.928	0.224	0.272	−0.267	0.300
Δ Triglyceride (mg/dL)	0.264	0.087	0.419	0.033	0.075	0.775
Δ HDL cholesterol (mg/dL)	−0.126	0.422	0.067	0.746	−0.321	0.209
Δ Blood glucose (mg/dL)	0.144	0.358	0.250	0.218	0.020	0.940
Δ Albumin (g/mL)	0.376	0.013	0.321	0.110	0.463	0.062
All days						
Δ Locomotive physical activity (METs·h/day)	0.200	0.200	0.002	0.991	0.389	0.123
Δ Non-locomotive physical activity (METs·h/day)	0.103	0.510	0.038	0.856	0.351	0.167
Δ Total physical activity (METs·h/day)	0.197	0.206	0.029	0.889	0.423	0.091
Δ Daily step count (steps per day)	0.226	0.145	−0.041	0.843	0.499	0.041
Δ Daily step hours (minutes/day)	0.008	0.958	−0.149	0.467	0.362	0.153
Δ Physical activity (1–3 METs)(minutes/day)	−0.152	0.332	−0.125	0.543	−0.346	0.174
Δ Physical activity (3–4 METs)(minutes/day)	0.191	0.219	0.083	0.687	0.389	0.123
Δ Physical activity (> 4 METs)(minutes/day)	0.143	0.359	−0.146	0.477	0.382	0.130
Hemodialysis days						
Δ Locomotive physical activity (METs·h/day)	0.151	0.334	0.074	0.721	0.279	0.278
Δ Non-locomotive physical activity (METs·h/day)	0.000	0.998	−0.103	0.616	0.139	0.595
Δ Total physical activity (METs·h/day)	0.113	0.472	−0.006	0.976	0.272	0.291
Δ Daily step count (steps per day)	0.152	0.330	−0.113	0.583	0.475	0.054
Δ Daily step hours (minutes/day)	0.030	0.850	−0.125	0.542	0.301	0.241
Δ Physical activity (1–3 METs)(minutes/day)	−0.337	0.027	−0.301	0.136	−0.442	0.076
Δ Physical activity (3–4 METs)(minutes/day)	0.104	0.508	−0.020	0.922	0.258	0.318
Δ Physical activity (> 4 METs)(minutes/day)	0.070	0.657	0.042	0.837	0.153	0.558
Non-hemodialysis days						
Δ Locomotive physical activity (METs·h/day)	0.157	0.314	−0.046	0.825	0.327	0.200
Δ Non-locomotive physical activity (METs·h/day)	0.125	0.424	0.083	0.686	0.311	0.225
Δ Total physical activity (METs·h/day)	0.184	0.238	0.041	0.844	0.352	0.166
Δ Daily step count (steps per day)	0.204	0.189	0.024	0.907	0.388	0.124
Δ Daily step hours (minutes/day)	−0.012	0.939	−0.120	0.560	0.208	0.424
Δ Physical activity (1–3 METs)(minutes/day)	0.038	0.807	0.035	0.864	0.022	0.935
Δ Physical activity (3–4 METs)(minutes/day)	0.182	0.243	0.114	0.579	0.308	0.230
Δ Physical activity (> 4 METs)(minutes/day)	0.124	0.429	−0.220	0.281	0.339	0.183

BMI, body mass index (kg/m^2); SBP, systolic blood pressure (mmHg); DBP, diastolic blood pressure (mmHg).
Δ: Changes in parameters with 1-year follow-up. Bold values are statistically significant ($p < 0.05$).

Johansen *et al.* also reported that patients on hemodialysis were less active than healthy sedentary controls, and this difference was demonstrated in older patients with the use of a tri-accelerometer and an activity questionnaire [13].

There have been several studies of the relationships among physical activity, physical fitness, and depression. Ragnarsdóttir *et al.* showed that moderate-intensity endurance training resulted in increased physical fitness in hemodialysis patients [14]. Leg-cycling exercise was shown by Storer *et al.* to improve not only cardiopulmonary fitness and endurance but also muscle strength, power, fatigability, and physical function in hemodialysis patients [15]. Using the Beck Depression Inventory-II (BDI) in their study of hemodialysis patients, Zhang *et al.* reported that daily physical activity was negatively correlated with the BDI depression score [16].

The relationships among the HRQOL, physical exercise, and/or physical activity in patients on chronic hemodialysis have also been described. De Lima *et al.* reported that physical exercise improved their chronic hemodialysis patients' QOL [17]. The Kidney Disease Quality of Life (KDQOL) physical composite score demonstrated moderate responsiveness to a 12-week physical exercise regimen in a study by Nonoyama *et al.* [18]. In other studies, the serum triglyceride level was significantly associated with EQ-5D scores [19], and 12-week resistance training exercises using elastic bands and sandbags were effective in decreasing triglyceride levels [20].

In our previous study [2], we evaluated the relationship between the HRQOL and physical activity by using a tri-accelerometer (Actimarker, Panasonic, Osaka, Japan) in Japanese patients on chronic hemodialysis in a cross-sectional study. A level of more than 4 METs of physical activity on non-hemodialysis therapy days was associated with EQ-5D scores, especially in the women. In the present study, changes in physical activity, especially daily step counts, were positively associated with changes in the HRQOL in the female chronic hemodialysis patients with a 1-year follow-up. In addition, changes in EQ-5D scores were weakly and negatively correlated with changes in physical activity (1-3 METs), which we suspect reflects the sedentary lifestyle on hemodialysis days in all patients ($r=-0.337$, $p=0.027$). Changes in EQ-5D scores were positively associated with changes in triglyceride levels in the men. Taken together, these results indicate that total daily physical activity may be important for improving the HRQOL in patients on chronic hemodialysis over a long period of time. In fact, a moderate level of physical activity was shown to have beneficial effects in patients on chronic hemodialysis [21].

However, in the present longitudinal study, changes in physical activity (>4 METs) on non-hemodialysis days were not associated with changes in EQ-5D scores as we previously observed [2]. In our previous cross-sectional study, we used the data of physical activity evaluated by Σ [metabolic equivalents $\times$ h per week (METs•h/w)], whereas in the present longitudinal study, we used the data of physical activity by steps per day and/or minutes per day. In addition, we used a different tri-accelerometer named the Active Style Pro (Omron Healthcare, Kyoto, Japan) in the present study. These differences in methods may have led to the different results.

There are potential limitations of this study. First, the 71 patients enrolled in this cross-sectional study might have been more health-conscious than the average patient. In addition, the 43 patients in the longitudinal study may have been even more health-conscious. Second, we could not clarify the mechanism underlying the relationship between physical activity and the HRQOL. Third, the relationship between the HRQOL and daily step counts was only noted in the women. A difference in the reference values of HRQOL and physical activity between men and women may have resulted in the gender differences in this study. In fact, the daily step counts in the women were higher than those in the men, whereas at baseline the HRQOL in the men was higher than that in the women. Nevertheless, it is reasonable that increasing physical activity can result in increasing HRQOL in patients on chronic hemodialysis. Further investigations with larger sample sizes are necessary to prove such a link.

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