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Effect of intradialytic weight resistance training exercise in sarcopenic hemodialysis patients: A randomized controlled trial

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Abstract

Background: Sarcopenia has a high prevalence in end-stage kidney disease (ESKD). However, there is limited evidence of resistance exercise in these patients.

Objective: The study investigated the effects of resistance exercise on muscle mass, strength, and physical functioning.

Method: Fifty-three patients were randomly assigned to resistance training exercise ($n = 26$) and standard exercise ($n = 27$) groups. All of the patients were diagnosed with sarcopenia by the Asian Working Group for Sarcopenia 2019 criteria.

Results: After 12 weeks, an improvement in leg muscle strength was significantly greater in the resistant exercise group compared with standard exercise (12.19 vs. 2.83 kg, $p < 0.001$). Appendicular skeletal muscle mass had a mean difference (1.01 vs. 1.02 kg/m^2, $p = 0.96$). Physical performance status had a mean difference (-2.3 vs. -18 s, $p = 0.42$). There were no serious adverse events.

Conclusion: Over a 12-week follow-up, resistance exercise improved muscle strength in sarcopenic ESKD patients. Muscle mass and physical performance showed no significant change, but there is still a trend demonstrating to improve.

KEYWORDS

hemodialysis, resistance exercise, sarcopenia

1 | BACKGROUND

Sarcopenia is a progressive muscle disease in three modalities: loss of muscle mass, muscle strength, and decreased performance status. Sarcopenia has a high incidence in hemodialysis patients 30%–70% and 25%–45% in peritoneal dialysis patients [1, 2]. Sarcopenia has negative outcomes, including an increase in mortality, cardiovascular events, loss of physical performance, risk of falling, decreased quality of life, and increased hospitalization cost. The main risk factor for sarcopenia is aging. Chronic kidney disease (CKD) is an abnormal protein catabolism that can be a secondary cause of sarcopenia by the mechanism of muscle breakdown and decreased muscle regeneration. The pathophysiology of sarcopenia in CKD patients is demonstrated in Figure 1. Patients with CKD and sarcopenia have a 33% higher mortality compared with individuals without sarcopenia [3]. End-stage kidney disease (ESKD) is a risk factor for sarcopenia. On the other hand, sarcopenia is a risk for CKD progression to ESKD. Diagnosis of sarcopenia is confirmed by the criteria from the Asian Working Group for Sarcopenia (AWGS) 2019 [4]. The criteria diagnosis is one clinical condition of sarcopenia and one of three modalities: decrease in appendicular skeletal muscle mass by dual-energy x-ray absorptiometry (DEXA scan) or bioelectrical impedance analysis (BIA), low muscle strength, or low physical performance. At present, from recent clinical trials, resistance exercise, nutritional supplementation, and vitamin D have been established as comprehensive therapeutics for sarcopenia in CKD patients. According to the K/DOQI guideline recommendation, hemodialysis patients should be encouraged to perform cardiovascular exercise at a moderate intensity for 30 min for most, if not all, days per week. Patients who are not currently physically active should start with very low levels and durations and gradually progress (C) [5]. The systematic review and meta-analysis from 21 randomized controlled trials (RCTs) reported moderate to a high-intensity resistance training exercise in hemodialysis patients significantly improved sarcopenic outcomes; muscle mass, muscle strength, and physical performance status. Whereas aerobic training exercises improved only hand grip strength and physical performance status [6]. However, several recent studies cannot conclude about resistance training prescription dose and duration of exercise, and most studies do not report adverse events. The limitation of evidence is that there were no clinical trials done in established sarcopenia from criteria diagnosis in hemodialysis patients. Therefore, we have studied the effect of intradialytic resistance training exercises by performing an RCT in established sarcopenia from AWGS 2019 criteria. The objective of this study is to find the impact of resistant exercise on outcomes, prescribed weight at initiation, and a protocol to step weight.

1.1 | Objectives

Primary outcome: The improvement of sarcopenic outcomes (muscle mass, muscle strength, and physical performance status).

Secondary outcome: Adverse events during training exercise.

2 | METHODS

2.1 | Trial design

The design and methods of this trial were a prospective, single-center, randomized, controlled trial performed at two hemodialysis units throughout Thailand. We randomly assigned patients in a 1:1 ratio via block of four into two groups. The groups were a progressive resistance training exercise (intervention group) and a standard exercise (control group). The patients were assigned to complete 12 weeks of resistance training that consisted of two supervised training for three sessions per week. All patients provided written informed consent. An independent data and safety monitoring committee reviewed pertinent safety data. Data were collected and analyzed by trial investigators. The authors interpreted the data, collaborated in the manuscript preparation, and aimed for the accuracy and completeness of the data and for the adherence to the trial based on the protocol. The first and last authors wrote the first draft of the manuscript and made

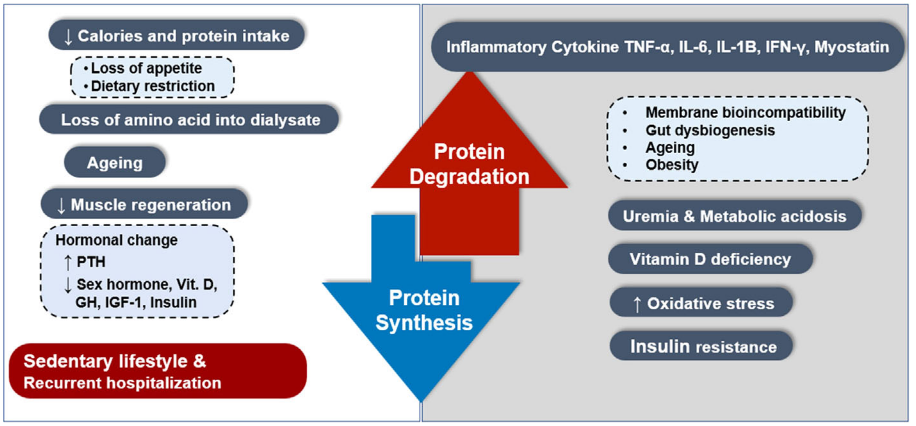

FIGURE 1 Pathogenesis of sarcopenia in chronic kidney disease. GH, growth hormone; IFN-γ, interferon-gamma; IGF-1, insulin-like growth factor 1; IL-1B, interleukin-1 beta; IL-6, interleukin-6; PTH, parathyroid hormone; ROS, reactive oxygen species; TNF-α, tumor necrosis factor alpha; Vit. D, vitamin D.

final decisions regarding the content of the submitted manuscript. All the authors had access to the trial data, critically reviewed the manuscript, and approved it for submission. The authors and their institutions were required to maintain data confidentiality during the trial.

2.2 | Trial participants

The patients were recruited from two dialysis centers under a single hospital from July 2022 to January 2023. Key eligibility criteria included ESKD patients undertaking hemodialysis three sessions per week, age 30–75 years old, and dialysis vintage more than 3 months. All the patients were diagnosed with established sarcopenia by AWGS 2019 criteria. The patients who had several conditions were excluded from our study; low life expectancy <6 months, status totally confined to bed, cancer, history of limb amputation, major surgery, trauma or severe hospitalized infection within the prior 3 months, acute coronary syndrome, untreatable intradialytic hypotension, uncontrolled hypertension with systolic blood pressure ≥200 mm Hg and diastolic blood pressure ≥120 mm Hg and recent decompensated heart failure. A full list of inclusion and exclusion criteria is provided in the Supporting Information Appendix S1. Before starting the study, patients gave their written informed consent. The study was approved by the institutional review board of the Thai army medical department.

2.3 | Trial procedure

The patients were tested in four parts. The first part is an appendicular skeletal muscle mass scan by The Styku 3D body scanner 72-0001. It had the evidence of accuracy. Compared with DEXA scan, R^2 is 0.99 [7]. The appendicular skeletal muscle mass <7.0 kg/m^2 in males and <5.4 kg/m^2 in females was the criteria for diagnosis of low skeletal muscle mass. Second, hand grip strength was assessed by a hydraulic hand dynamometer (Jamar®; Sammons Preston, Bolingbrook, USA). The hand grip strength of <28 kg in males and <18 kg in females was the criteria for diagnosis of low muscle strength. Thirdly, the subjects were tested a lower extremities strength with a leg dynamometer. Finally, physical performance was tested by five times sit to stand test (5STST). After initial evaluation, the subjects who fit in AWGS 2019 criteria were randomly assigned into two groups. An intervention group was assigned to complete 12 weeks of resistance training that consisted of two supervised training for three sessions per week. During the protocol, patients were advised to stop extra resistance exercises at home. The patients were assigned to lift sand back on their legs in three sets/session of hemodialysis. We start the exercise protocol after the first hour of the session. The patients were tested for one repetitive maximum weight (1RM) before intervention. A 1RM is defined as *the maximal weight an individual can lift for only one repetition with the correct technique*. The principle of resistance exercise programming is that patients need to be greater than 50%–60% 1RM to promote positive muscle adaptation and intensity and may try to progress to 70%–85% 1RM to optimize gain in muscular strength. However, this should not be more than 85% 1RM to avoid muscular injury [8]. However, the rationale in the situation of our subjects in sarcopenic patients with ESRD setting, we start at 30%–50% 1RM and step up 30%–50% every 4 weeks until 12 weeks, as shown in Table 1. The exercise prescription dose and step-up-down protocol were demonstrated in Tables SA1–SA3. The patients allocated to the control group will receive their standard exercise by lifting their

TABLE 1 The initial resistance exercise program and the step of weight prescription in the next 4 and 8 weeks.

1RM (kg)	Initial prescription (kg)	4 weeks (kg)	6 weeks (kg)
1	0.5	1	1.5
2	1	1.5	2
3	1	2	3
4	1.5	2	3
5	1.5	2	3
6	2	3	4
7	2.5	3.5	5
8	3	4	6
9	3	4	6
10	3	4	6

Abbreviation: 1RM, 1 repetitive maximum weight.

legs according to their own body weight. Through the 12-week period, all patients will be instructed to maintain the standard treatment. The data on compliance with exercise was collected at every session, and the adverse events were recorded. If the subjects had a compliance lower than 80%, they would be withdrawn from the study. In addition, the dietician conducted a food interview with the subjects and advised them to adequate energy and protein intake (1.0–1.2 g/kg) every 4 weeks.

2.4 | Trial assessment and outcomes

At the time of recruitment, baseline data were collected by physicians at face-to-face visits with the use of a standardized questionnaire. Laboratory data were obtained at baseline. Appendicular skeletal muscle mass, hand grip strength, legs dynamometer strength test, and 5STST were performed before and after 12 weeks of training protocol. The primary endpoint was the mean difference before and after the training protocol of 12 weeks of appendicular skeletal muscle mass, leg strength, and physical performance. Secondary outcomes were adverse events resulting from resistance exercise training. We reported these as event per person and event per 100 sessions.

2.5 | Statistical analysis

The sample size was calculated from the result of improvement of leg strength from resistance training exercise in hemodialysis patients [9]. The level of significance is $\alpha = 0.05$ and power $\beta = 80\%$, resulting in 26 cases in each group (total of 53 cases). The data was analyzed by SPSS 18.0 software (version 18.0; SPSS Inc, Chicago, IL). Data with normal distribution was reported as mean ± standard deviation and non-normal distributed data was reported as median and interquartile ranges. An independent sample *t*-test, chi-square test (χ^2 test), Mann–Whitney *U* test, and Fisher's exact test were used. All analyses were based on intention to treat analysis.

3 | RESULTS

3.1 | Patient characteristics

From the initial study subjects of 53 patients, 26 completed the 12-week intervention, and 27 completed the 12-week follow-up in the control group. There were no dropouts in both groups. The detail is summarized in Figure 2.

Baseline population characteristics were well-balanced between the two trial groups (Table 2). The mean age of the patients was 53 years and 68% of these were men. The patients have dialysis vintage for 3.6–4.4 years. The major etiologies of ESKD are diabetic nephropathy and hypertensive nephrosclerosis. The laboratory marker for sarcopenia; hemoglobin, albumin, dialysis adequacy, normalized protein catabolic rate, blood urea nitrogen, electrolyte, calcium, phosphate, intact

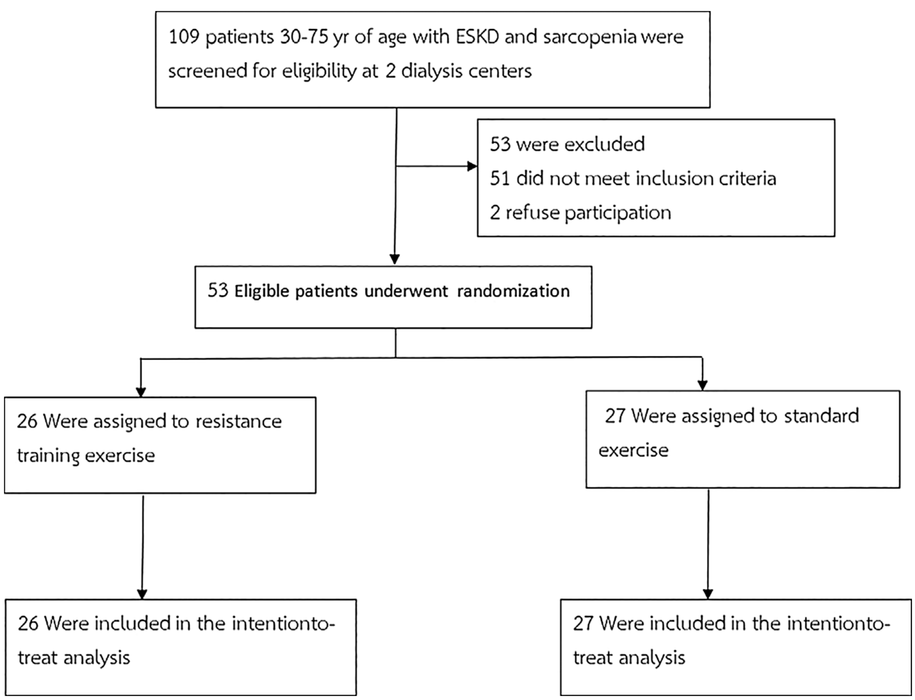

FIGURE 2 Screening, randomization, and follow-up.

TABLE 2 Baseline population characteristics.[a]

	Intervention group (n = 26)	Control group (n = 27)	p Value
Age (years)	56 ± 9.81	49.5 ± 11.05	0.029*
Male sex—no. (%)	18 (69)	18 (67)	0.842
Body mass index[b]	23.5 ± 4.8	22.8 ± 3.9	0.544
BSA (m^2)	1.58 ± 0.65	1.49 ± 0.14	0.476
Dialysis vintage (years)[c]	3.6 (1.51, 6.43)	4.44 (1.66, 5.28)	0.972
Comorbidity—no. (%)			
Hypertension	26 (100%)	22 (81.5%)	0.021*
T2DM	9 (34.6%)	10 (37%)	0.854
DLP	9 (34.6%)	4 (14.8%)	0.094
Stroke	1 (3.8%)	1 (3.7%)	0.978
CVD	2 (7.7%)	1 (3.7%)	0.53
Etiology of ESKD—no. (%)			0.789
Glomerular	3 (11.5%)	4 (14.8%)	
DN	8 (30.8%)	10 (37%)	
HT	14 (53.8%)	11 (40.7%)	
Obstructive uropathy	0 (0%)	0 (0%)	
CTIN	0 (0%)	1 (3.7%)	
Unknown	1 (3.8%)	1 (3.7%)	
Predialysis blood pressure (mm Hg)			
Systolic	150.1 ± 15.8	152.6 ± 23.9	0.655
Diastolic	76.1 ± 12.4	75.9 ± 12.6	0.948
Nutritional status (NAF)[d]			
A	14 (53.8%)	11 (40.7%)	0.433
B	12 (46.2%)	15 (55.6%)	
C	0 (0%)	1 (3.7%)	
Hemoglobin (g/dL)	10.47 ± 0.93	10.21 ± 2.05	0.566
Albumin (mg/dL)	4.2 ± 0.59	4.36 ± 0.48	0.303
Dialysis adequacy (Kt/V)	1.75 ± 0.35	1.69 ± 0.3	0.512
nPCR	1.15 ± 0.25	1.2 ± 0.22	0.451
Sodium (mEq/L)	136.81 ± 2.95	137.89 ± 2.81	0.178
Potassium (mEq/L)	4.45 ± 0.54	4.38 ± 0.53	0.663
Bicarbonate (mEq/L)	25 ± 2.7	25.15 ± 2.58	0.839
Calcium (mg/dL)	9.68 ± 0.93	9.44 ± 0.86	0.340
Phosphate (mg/dL)	5.37 ± 1.55	5.12 ± 1.91	0.613
iPTH (pg/mL)[c]	398.5 (276, 801)	430 (306, 585)	0.873
Ferritin (ng/mL)[c]	322.5 (223, 587)	360 (232, 489)	0.845
Transferin saturation (%)	30.17 ± 10.44	30.41 ± 16.25	0.950
Cholesterol (mg/dL)	80.42 ± 26.2	97.81 ± 32	0.035*
BUN	62.77 ± 13.81	67.89 ± 24.6	0.353
1RM (kg)[e]	6.69 ± 1.69	6.44 ± 1.63	0.589
Total lean muscle mass (kg/m^2)	43.69 ± 9.61	45.32 ± 9.05	0.527
Appendicular skeletal muscle mass (kg/m^2)	5.2 ± 1.07	5.19 ± 0.85	0.967

TABLE 2 (Continued)

	Intervention group ($n = 26$)	Control group ($n = 27$)	p Value
Right leg volume (L)	5.24 ± 1.33	5.37 ± 1.13	0.707
Left leg volume (L)	5.23 ± 1.22	5.32 ± 1.1	0.778
Hand grip strength (kg)	21.98 ± 7.26	24.24 ± 10.13	0.356
Leg dynamometer strength (kg)	46.67 ± 26.53	53.29 ± 30.16	0.401
5 STST (s)	11.55 ± 3.52	12.36 ± 5.05	0.501

Abbreviations: 5STST, five times sit to stand test; BSA, body surface area; BUN, blood urea nitrogen; CTIN, chronic tubulointerstitial disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; DLP, dyslipidemia; DN, diabetic nephropathy; HT, hypertension; iPTH, intact parathyroid hormone; nPCR, normalized protein catabolic rate; SBP, systolic blood pressure; T2DM, Type 2 diabetes mellitus.
[a]Plus–minus values are means ± SD.
[b]The body mass index is the weight in kilograms divided by the square of the height in meters.
[c]Median (range).
[d]NAF, nutrition alert form score; A, normal-mild malnutrition; B, moderate malnutrition; C, severe malnutrition.
[e]1RM, one repetition maximum was defined as the maximum weight that a person can possibly lift for one repetition.
*statistical significant.

parathyroid hormone, and iron study were similar in both groups. The nutritional status ranged from normal to moderate malnutrition according to the nutrition alert form. The patients who fit in criteria of sarcopenia were randomized into two groups and their baseline of being diagnosed with sarcopenia was not different between both groups. An appendicular skeletal muscle mass was 5 kg/m^2, that included in the criteria from AWGS 2019 (male < 7.0 kg/m^2, female < 5.4 kg/m^2). In addition, 1RM was around 6 kg in both groups. The compliance rate was more than 80%, and no subject was withdrawn during the study. The compliance rate is demonstrated in Table SA4. Energy and protein intake by food interview during protocol was demonstrated in Table SA5.

3.2 | Primary outcomes

The primary outcomes of the study were appendicular skeletal muscle mass, leg dynamometer strength, and physical performance by 5STST. The effect of resistance exercise on sarcopenic outcomes was demonstrated in Table 3. After resistance exercise protocol for 12 weeks, a benefit with strong statistical improvement of mean difference in dynamometer strength of legs 9.4 kg (95% confidence interval [CI], 5.0–13.6; $p < 0.001$) was shown. Moreover, standard exercise by an individual's own weight showed a significant benefit for improvement of leg strength 2.8 kg (95% CI, 0.1–5.5; $p = 0.04$). Figure 3.

The appendicular skeletal muscle mass was increased to 1.01 kg/m^2 (95% CI, 0.8–1.22; $p < 0.001$) in an intervention group and 1.02 kg/m^2 (95% CI, 0.82–1.22; $p < 0.001$) in the control group. Although there was no significant difference between both groups, the appendicular skeletal muscle mass is a significant increase in each group. The results of right and left leg volume were nonsignificant.

The physical performance status was assessed by 5STST, with the results showing a significant benefit for improvement of 5STST in two groups; −2.27 s (95% CI, −3.01 to −1.53; $p < 0.001$) and −1.8 s (95% CI, −2.73 to −0.86; $p = 0.001$). However, there was no significant difference between both groups.

3.3 | Secondary outcomes

We recorded every adverse event during the 12-week protocol. The patients had a few adverse events; muscle pain, dyspnea, arthralgia, fatigue, cramping, and intradialytic hypertension, as shown in Table 4. Muscle pain occurred more significantly in the intervention group. However, it could be relieved by supportive care. We found two cases who fell at home, in which one had an accident in the bathroom and the other one had an accident while walking up the stairs.

4 | DISCUSSION

An exercise intervention for the prevention and treatment of sarcopenia from a recent systematic umbrella review showed a positive and significant effect of a resistance training exercise on muscle mass, muscle strength, and physical performance in elderly patients [10]. Intensity was based on the percentage of one repetition maximum (1RM) used for a given exercise: low intensity (<60% 1RM), low/moderate intensity (60%–69% 1RM),

TABLE 3 The effect of resistance exercise on sarcopenic outcomes.

	Intervention group ($n = 26$)	Control group ($n = 27$)	p Value
Appendicular skeletal muscle mass (kg/m^2)			
Pre-training	5.2 ± 1.07	5.2 ± 0.9	0.967
Post-training	6.2 ± 1.3	6.2 ± 1.1	0.990
Mean difference (95% CI)	1.01 (0.8, 1.2)	1.02 (0.82, 1.2)	0.961
p Value (within group)	<0.001*	<0.001*	
Right leg volume (L)			
Pre-training	5.2 ± 1.3	5.4 ± 1.1	0.707
Post-training	6.2 ± 1.3	6.4 ± 1.5	0.653
Mean difference (95% CI)	0.99 (0.69, 1.29)	1.04 (0.8, 1.27)	0.796
p Value (within group)	<0.001*	<0.001*	
Left leg volume (L)			
Pre-training	5.2 ± 1.2	5.3 ± 1.1	0.778
Post-training	6.2 ± 1.3	6.3 ± 1.4	0.680
Mean difference (95% CI)	0.93 (0.69, 1.18)	1 (0.76, 1.24)	0.694
p Value (within group)	<0.001*	<0.001*	
Leg dynamometer strength (kg)			
Pre-training	46.7 ± 26.5	53.3 ± 30.2	0.401
Post-training	58.9 ± 26.1	56.1 ± 28.6	0.716
Mean difference (95% CI)	12.2 (8.6, 15.8)	2.8 (0.1, 5.5)	<0.001*
p Value (within group)	<0.001*	0.04*	
5 STST (s)			
Pre-training	11.6 ± 3.5	12.4 ± 5.1	0.501
Post-training	9.3 ± 2.4	10.6 ± 4.3	0.178
Mean difference (95% CI)	−2.3 (−3.0, −1.5)	−1.8 (−2.7, −0.9)	0.420
p Value (within group)	<0.001*	0.001*	
Body weight			
Pre-training	63.7 ± 15.1	63.6 ± 13.8	0.976
Post-training	65.3 ± 13.5	64.8 ± 13.6	0.893
Mean difference (95% CI)	1.6 (0.1, 3.0)	1.2 (0.3, 2.1)	0.651
p Value (within group)	0.037*	0.014*	

Abbreviation: CI, confidence interval.
*statistical significant.

moderate/high intensity (70%–79% 1RM), and high intensity (≥80% 1RM). A high-intensity training program obtains a maximal muscle strength gain. Our study was done in ESKD patients with sarcopenia who had a risk for frailty compared with healthy elderly. Therefore, we initiated the intensity of the protocol of resistance training at 30% 1RM with the rationale of preventing musculoskeletal injury. The result showed the strongly positive significance of resistance training exercises in leg strength. Moreover, another point of interest is the statistically significant improvement of leg strength in a standard exercise group. We can conclude that low-intensity resistance exercise with just 30% 1RM initially or exercise with an individual's own body weight could improve muscle strength as one of the sarcopenic outcomes. To compare with a recent study, the improvement of strength in sarcopenia is similar to non-sarcopenia around 12–13 kg at 12 weeks [11]. In addition, we demonstrated that resistance exercise and standard exercise had a positive benefit on sarcopenic outcomes, including appendicular skeletal muscle mass and physical performance status in each group. However, there are no

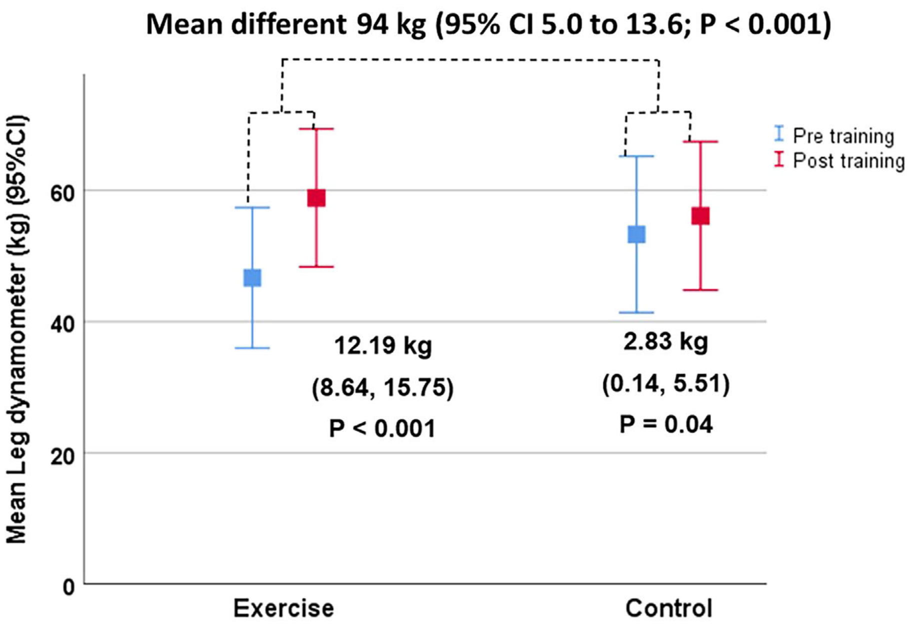

FIGURE 3 The mean difference in leg dynamometer strength between the intervention and control group.

TABLE 4 Adverse events.[a]

	Intervention group ($n = 26$)	Control group ($n = 27$)	p Value
Muscle pain			
Event per person	42.3 (25, 61.3)	3.7 (0.4, 16)	0.001*
Event per 100 sessions	3.17 (0.79, 5.49)	0.53 (0, 1.59)	0.043*
Dyspnea			
Event per person	15.4 (5.4, 32.5)	7.4 (1.6, 21.7)	0.36
Event per 100 sessions	0.55 (0, 1.1)	0.21 (0, 0.5)	0.298
Arthralgia			
Event per person	23.1 (10.3, 41.5)	7.4 (1.6, 21.7)	0.111
Event per 100 sessions	1.53 (0.22, 2.8)	0.21 (0, 0.5)	0.053
Fatigue			
Event per person	7.7 (1.6, 22.5)	7.4 (1.6, 21.7)	0.969
Event per 100 sessions	0.55 (0, 1.33)	0.32 (0, 0.78)	0.591
Cramping			
Event per person	15.4 (5.4, 32.5)	0	0.034*
Event per 100 sessions	0.76 (0, 1.58)	0	0.071
Falling			
Event per person	11.5 (3.4, 27.7)	0	0.069
Event per 100 sessions	0.33 (0.05, 0.7)	0	0.083
Intradialytic hypotension			
Event per person	7.7 (1.6, 22.5)	0	0.142
Event per 100 sessions	0.44 (0, 1.32)	0	0.327

[a]Event per person reported as percent, 95% CI. Event per 100 sessions reported as number of events, 95% CI.
*statistical significant.

significant differences between groups. This was because we did not compare resistance exercise and non-exercise, but we compared with standard exercise by the individual's own body weight instead. According to a recent study, the rapid initial step of muscle adaptation is an increase in muscle strength and power in 6–12 weeks, followed by slowed progression as the muscle grows in 3–6 months [12]. From the outcomes of several previous studies, the patients whose sarcopenia have a trend of improved muscle mass from resistance exercise were not different compared with non-sarcopenic patients. However, strength and power always adapt before muscle mass. Thus, we can conclude that the short-term outcome of resistance exercise is strength of muscle and the long-term outcomes are appendicular muscle mass and physical performance. The important benefit is each 1 kg/m^2 increase in appendicular skeletal muscle mass change was associated with a reduced risk of cardiovascular disease [13]. The final outcome, the improvement of physical performance, usually follows strength adaptation. An assessment with 5STST is a commonly used indicator of physical functioning, and the results are highly correlated with falling risks, cognitive ability, and neuromuscular function. The advantage of the improvement of physical performance was presented in stroke, a minimal clinically important difference of 5STST was around 3 s, which has evidence for gait speed recovery and improved household ambulators [14]. According to previous studies of non-sarcopenic ESKD patients, physical function often improved after a 12-week protocol. From our study, the physical function was not different between groups at the 12-week protocol, ESKD patients with sarcopenia may require a longer time in muscle recruitment and movement implementation compared with those who are non-sarcopenia. Future RCT studies are suggested to apply the effect of resistance exercise comparing patients with and without sarcopenia in ESKD patients.

The resistance training exercise is safe for the prevention and treatment of sarcopenia. The common adverse event is muscle pain that usually happens in 2–3 weeks at the initial step of exercise and can be relieved by supportive treatment. When the patients can tolerate with weight, they can go on with exercise training. The important adverse event is falling. The healthcare provider should evaluate the risk of falling and correct it accordingly.

Nowadays, there is insufficient evidence to provide optimal dosage of exercise recommendations. According to a systematic review of intradialytic resistance exercise, previous studies used different exercise protocols. They provide 2–3 sets of 8–10 repetition, three times per week, and assigned intensity of 15–17 on Borg's RPE (rating of perceived exertion) scale. Some studies used progressive free-weight exercise with a rubber band. The results show a benefit for improving muscle mass, muscle strength, and physical performance. However, they were cohort studies lacking evidence of established sarcopenic ESKD. Moreover, previous studies did not mention adverse events [15]. 1RM is repetition maximum weight. It defines the maximal weight that the patients can lift for only one repetition. According to recent studies, an initial step of 60% 1RM can improve sarcopenic outcome in the general population with sarcopenia. However, our study was done in sarcopenic ESKD patients who had a risk for frailty. Therefore, we initiated an intensity of resistance at 30% 1RM with the rationale of preventing musculoskeletal injury.

The strength of this study is a complete RCT study. We completely assessment of three modalities of sarcopenic outcomes. Patients in both groups had supervised training by two physical therapists. Moreover, the compliance and adverse events were recorded in every session.

The limitation was that our protocol is a short protocol of 12 weeks, although it showed significant benefits in muscle strength. However, if we postpone the protocol to 24 weeks or more, its benefits in muscle mass and physical performance outcome in long-term muscle adaptation might be demonstrated.

4.1 | Clinical application

We recommend a prescription protocol for resistance training exercises in sarcopenic ESKD patients. Initiation with 30% 1RM and progressing steps up 30%–50% of initial weight every 4 weeks are recommended. In addition, exercise for three sessions per week with three sets of 10 repetitions is also recommended.

5 | CONCLUSION

Our study explored the changes over time in components of sarcopenia in ESKD patients. Over a 12-week follow-up, resistance exercise training improved muscle strength in sarcopenic ESKD patients, but no significant changes in muscle mass and physical frailty compared with standard exercise. However, resistance exercise training was not associated with serious adverse effects.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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