Influences of high *vs*. low-intensity exercises on muscle strength, function, and quality of life in post-COVID-19 patients with sarcopenia: a randomized controlled trial

A.A. IBRAHIM[1], I.M. DEWIR[2], S.T. ABU EL KASEM[3,4], M.M. RAGAB[3], M.S. ABDEL-FATTAH[5], H.M. HUSSEIN[1,3]

[1]Department of Physical Therapy, College of Applied Medical Sciences, University of Ha'il, Ha'il, Saudi Arabia
[2]Department of Physical Therapy, College of Applied Medical Sciences, Taif University, Taif, Saudi Arabia
[3]Department of Basic Sciences, Faculty of Physical Therapy, Cairo University, Giza, Egypt
[4]Department of Basic Sciences, Faculty of Physical Therapy, Galala University, Suez, Egypt
[5]Department of Physical Therapy for Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt

Abstract. – OBJECTIVE: The aim of this study was to compare the effectiveness of high *vs*. low-intensity exercise training on muscle strength, physical function, and quality of life in post-COVID-19 patients with sarcopenia secondary to chronic kidney disease (CKD).

PATIENTS AND METHODS: 82 subjects were randomized into 2 groups: high intensity (HIG, n=42), which received high-intensity resistance training, and low intensity (LIG, n=40), which conducted low-intensity aerobic activities. Exercises were performed for 30 min, 3 times per week for 6 weeks. A handheld dynamometer, pinch press, and 1 min sit-to-stand (STS) test were used to assess muscle strength. Modified physical performance test and sarcopenia Quality of Life questionnaire (SAR-QoL) were used to assess function and quality of life, respectively. Measures were collected before and at the end of the treatment program.

RESULTS: Participants were similar at baseline. The within-group comparisons demonstrated statistically significant improvement in both HIG and LIG groups in all outcome measures ($p<0.001$). Between groups, comparisons revealed statistically significant better achievements with high effect size in Modified Physical Performance Test (MMPT) ($p<0.001$, $d=1.28$), handgrip ($p<0.001$, $d=3.6$), STS ($p<0.001$, $d=2.38$), and SAR-QoL ($p<0.001$, $d=3.24$) in favor of the HIG. On the other hand, pinch press strength was equally improved in both groups ($p=0.09$, $d=0.36$).

CONCLUSIONS: High-intensity exercise is better than low-intensity exercises in post-COVID-19 patients with sarcopenia secondary to chronic kidney disease regarding muscle strength, physical function, and quality of life.

Key Words:
Resistance, Performance, Function, Kidney.

Introduction

Sarcopenia is a prevalent chronic disease caused by aging and is characterized by a reduction in muscle strength and mass[1]. Consequently, deterioration in physical function and quality of life[2] usually takes place. Sarcopenia is associated with a higher risk for stroke, frailty[3], and mortality[4]. Generally, there are different causes of sarcopenia, including chronic kidney diseases (CKD)[5], lack of physical activity, inflammatory mediator activation, mitochondrial dysfunction, hormonal changes, environmental factors, and loss of neural junctions[6].

Patients with CKD already suffer from decreased functional reserve due to increased catabolism, higher protein wasting, and other metabolic disorders[7,8]. Additionally, the decline in physical function due to the deterioration of muscle mass, power, and strength could significantly decrease balance and increase the risk of falling in these populations[9].

After the pandemic of COVID-19 and the mandatory quarantine of patients during the recovery period, CKD patients with sarcopenia who were infected with COVID-19 were deprived of regular physical rehabilitation activities and forced

 Corresponding Author: Ahmed Abdelmoniem Ibrahim, Ph.D; e-mail: a.abdalmoniem@uoh.edu.sa

to assume a more sedentary lifestyle which consequently magnifies all health risks[10] and jeopardized the subject's vitality[11].

Exercise has been proposed as one of the solutions for sarcopenia-associated symptoms[1], so they were studied in previous literature[12-18]. Muscle strength, physical function, balance, and quality of life were the outcomes of interest in the majority of these studies. Additionally, variations of sarcopenia patients were investigated; for example, obese patients with sarcopenia were the sample in one study[16], sarcopenia secondary to COVID-19[12] or associated with CKD[17] was studied in a single study, while sarcopenia secondary to aging was the concern in another study[14].

Moreover, variation in the mode of exercise delivery was observed when group therapy[14], fun type of exercises[15], home-based[13,14], resistance[16-18], and aerobic activities[12] were conducted by different researchers. Unfortunately, no studies compared patients to resistance training with high-intensity *vs.* low-intensity aerobic exercises, especially in chronic kidney patients with sarcopenia who had recently recovered from COVID-19 infection.

After COVID-19 infection, both lung function and peripheral muscle integrity might be affected, and so it might have a negative effect on physical performance and quality of life (QoL). Additionally, some patients may suffer from post-intensive care syndrome that affects their mental health and magnify the effect of sarcopenia in this group of patients[19].

This study aimed to compare the effectiveness of high *vs.* low-intensity exercises on muscle strength, physical function, and quality of life in post-COVID-19 patients with sarcopenia secondary to CKD. The research hypothesis is that both high and low-intensity exercises will be equally effective for post-COVID-19 patients with sarcopenia secondary to CKD.

Patients and Methods

The study followed the declaration of Helsinki and was reported as per the CONSORT statement for reporting randomized controlled trials. Ethical approval was granted by the University of Ha'il Ethical Committee Board (No.: H-2022-342) and was registered at clinicaltrials.gov (No.: NCT05593471). A consent form was signed by all participants before joining the study.

Design

This study was designed as a double-blind, randomized, controlled trial. This study was conducted between January 15th and March 20th, 2023, in the Ha'il Region Hospitals, Saudi Arabia.

Participants

Ninety-one chronic kidney patients who recently (within 1-2 months) recovered from COVID-19 infection were screened; of them, 82 met the inclusion criteria and signed the consent to participate in the study. The inclusion criteria were: to be diagnosed with sarcopenia secondary to CKD, to have been infected by COVID-19 and recovered 1-2 months ago, a score of 4 or more on SAR-QoL questionnaire, and to have no severe comorbidities hindering their participation.

The exclusion criteria were medications affecting cognitive functions, balance abilities, or muscle performance, current COVID-19 infection, inflammatory, neurological, or cardiovascular diseases, chronic chest disease, and mental impairments.

Interventions

For both groups, each session started with 5 minutes of passive stretching exercises that were performed as a warmup. Another 5 minutes of pace walk in place was performed as a cooling down after finishing the exercise intervention.

High-Intensity Exercise

This type of exercise was performed by the participants in the high-intensity exercise group (HIG). 30 min of progressive resistance training were performed where theraband with different colors, dumbbells, and sandbags were used to apply the resistance. For using theraband, at the beginning of the exercise program, the patients were trained to wrap the bands around their hands to make sure the bands do not slip during exercise; patients were instructed to use the elastic bands of different tensile strengths by pulling on the band in the same position. While, for using sandbags, the patients were asked to wear sandbags weighing 1-3 kg around each of their ankles then, they were asked to wear sandbags that were one kg heavier than the ones they were wearing previously. Finally, for using dumbbells, patients were asked to carry on their hand with the appropriate weight according to the 10-repetition maximum and start the exercise session. The exercised muscles were (knee extensors, elbow flexors, chest muscles, hip adductors and abductors, abdominal muscles, back muscles, and hand grip muscles)[20]. The intensity of exercise was determined by the load, which was kept at 65% of the 10-repetition maximum throughout the program duration[21]. The repetitions of each exercise were kept at a fixed value of 2 sets of 10-12 repetitions per session (exercises stopped if the patient reached fatigue level). A 2-minute rest interval was allowed between each set of exercises. For progression, the 10-repetition maximum (10 RM) test was performed on a weekly schedule, and the amount of resistance was adjusted accordingly to keep the resistance at 65% of the new value of the 10 RM.

Low-Intensity Exercise

30 minutes of the aerobic exercise program was conducted by the participants in the low-intensity exercise group (LIG). Arm and leg ergometer (Arm Crank, Panatta Sport, Apiro, Italy) was used to train both upper and lower body muscles. The intensity of the exercises was fixed at a 3-4 level on the Rate of Perceived Exertion (RPE) scale. This scale is a valid and reliable tool for assessing exercise intensity[22]. Sessions were performed 3 times per week for 6 weeks[12,23].

Outcomes

All outcomes were collected before and after the end of the intervention period. A therapist with 15 years of experience was responsible for the initial screening of the subjects and data collection.

Muscle Strength

Isometric hand-grip strength of the dominant hand was assessed using the procedures performed in a recent study[24], while a Lafayette push hand-held dynamometer (model 01163, Lafayette Instrument Co., Lafayette, IN, USA) was used to collect data. This dynamometer has a dual-pointer system to record the maximum effort in Kg. The device is a valid and reliable tool for assessing isometric hand muscle strength[25]. The participants were asked to sit on a chair with armrests. The tested arm was slightly abducted at the shoulder, and the elbow was at 90° of flexion. Participants were asked to squeeze the handle of the device as hard as possible and then relax. This procedure was repeated three times with 1-minute rest intervals. The average of the three readings was used for the analysis.

Pinch press strength was assessed for the thumb adductors in the dominant hand. The strength of such muscles is important to maintain the grasp pattern during regular hand activities. Lack of muscular strength and coordination might lead to difficulty with daily activities that require fine motor strength[26]. The purpose and procedures of testing were described to the participants. Each participant was tested in a quiet room in an upright seated position. The upper limbs were kept adducted against the body with elbows at 90° of flexion. Participants were asked to press the device between the thumb and index fingers as hard as possible for 3 trials, to minimize the effect of fatigue, three-minute resting periods were allowed between tests. The average of the 3 trials was calculated and used for analysis[27].

Sit to stand in 30 seconds (STS- 30) is a well-known test that can be used to identify the strength and power of the lower quadrant in older individuals[28]. The validity and reliability of this test have been assessed previously. To perform this test, participants were asked to sit on a chair, then stand up and sit down again as fast as they could within 30 seconds, keeping their arms folded across the chest[29-31]. The maximal number of chair stands completed for 30 seconds was recorded and used for analysis.

Physical Function

The basic and complex Activities of Daily Living (ADL) were assessed by the Modified Physical Performance Test (MPPT). This test consists of nine standardized tasks: walking 15.2 meters, doing a 360° turn, putting on a coat, picking up a coin, rising from a chair, lifting a book, and climbing stairs in 2 variations, The maximum score that can be achieved in the MPPT test is 36 with the following cut-off points: from 32-36 means no physical disabilities, 25-31 indicates mild physical disability and 17-24 indicates moderate physical disability[32].

Quality of Life

To assess the quality of life, participants were asked to fill out a validated Arabic Sar-QoL questionnaire[33]. This questionnaire consists of 22 questions, each of which has 4-point answers options. These questions cover seven domains assessing the health of patients with sarcopenia[12]. The total scoring ranged between 0, which indicated the worst health status, to 100, which indicated the best health status[34].

Sample Size

The sample size calculations were based on the outcomes of the Sar-QoL scores. According to the guidelines described by Witham et al[35], to obtain a minimal clinically important difference of 17 points, with 80% power (adjusted), 2 equal groups of 34 subjects should be included per group. The number was raised to 40 per group to compensate for withdrawal.

Randomization, Concealment, and Blinding

Immediately after the initial assessment, participants were randomly assigned to either the HG or LG groups. Randomization was conducted using a computer-generated randomized sequence. Randomization data were concealed from all researchers and kept safe with a coworker who was involved neither in assessment nor treatment. To conceal the randomization sequence, a specific identification number was assigned for each participant. The participants and the assessor were kept blindfolded throughout the study.

Statistical Analysis

Version 23 of the Statistical Package of Social Science (SPSS, IBM Corp., Armonk, NY, USA) was used for analysis. Intention-to-treat analysis was adopted. Descriptive statistics (mean ± SD) were calculated for all variables. When data were normally distributed, paired and Unpaired *t*-tests were used to assess the within and between groups changes. When data were not normally distributed, Wilcoxon signed-rank and Mann-Whitney U tests were used to conduct the within and between-group comparisons, respectively. The level was set at $p<.05$. Cohen's *d* formula was used to calculate the clinical effect size (ES) between groups.

Results

This study included 82 participants, 42 in the HIG aged 60.45±4.73 years and 40 in the LIG aged 59.15±4.3. Most of the participants were males whereas 3 and 2 female participants were allocated to the HIG and LIG, respectively. Participants were similar regarding demographic characteristics (Table I) as well as comorbidities such as diabetes mellitus, hypertension, atherosclerosis, and body composition (Figure 1). Furthermore, participants underwent tailored nutritional support as described by their physicians according to each case[1].

No significant adverse effects were reported throughout the study. Additionally, all participants were committed to the treatment sessions, and no dropout was reported (Figure 2).

The within-group comparisons demonstrated statistically significant improvement in both HIG and LIG groups ($p<0.001$) in favor of all outcome measures (Tables II and III). The highest mean difference (MD) was observed in the handgrip strength demonstrated by HIG (MD=24.12). The lowest MD was the value of the STS in the 60-second test demonstrated by the LIG (MD=3.25).

Between groups, comparisons revealed statistically significant better achievements in MPPT, handgrip, STS in 60 seconds, and Sar-QoL ($p<0.001$) in favor of the HIG. High effect size, as represented by Cohen's *d* formula, was evident in the MPPT, STS in 60 mins, and Sar-QoL. On the other hand, pinch press strength was equally improved in both groups at the end of the treatment ($p=0.09$, $d=.36$). These findings were presented in Tables III and IV.

Discussion

This study compared the effects of high and low-intensity exercises on muscle strength, physical function, and quality of life in post-COVID-19 patients with sarcopenia secondary to CKD. This trial found that while all outcomes were better af-

Table I. Demographic data of the participants.

Variable	HIG (n = 42)		LIG (n = 40)		*t*	*p*
	Mean	SD	Mean	SD		
Age	60.45	4.73	59.15	4.31	1.31	.194
Height	158.80	4.87	156.25	5.49	2.23	.028
Weight	79.14	9.27	80.95	10.79	-.814	.418
BMI	27.04	5.13	29.12	4.98	1.86	.066

N, number; HIG, high-intensity group; LIG, low-intensity group; SD, standard deviation; BMI, body mass index; *t*, t-value; *p*, significant level.

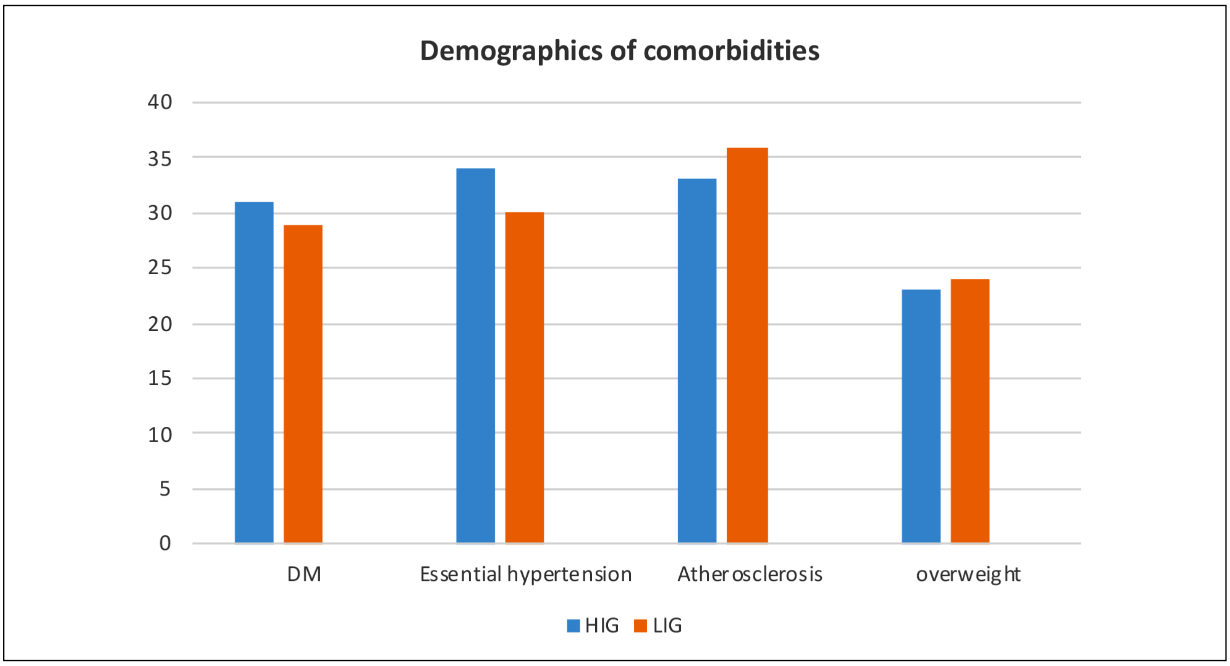

Figure 1. Distribution of comorbidities among groups.

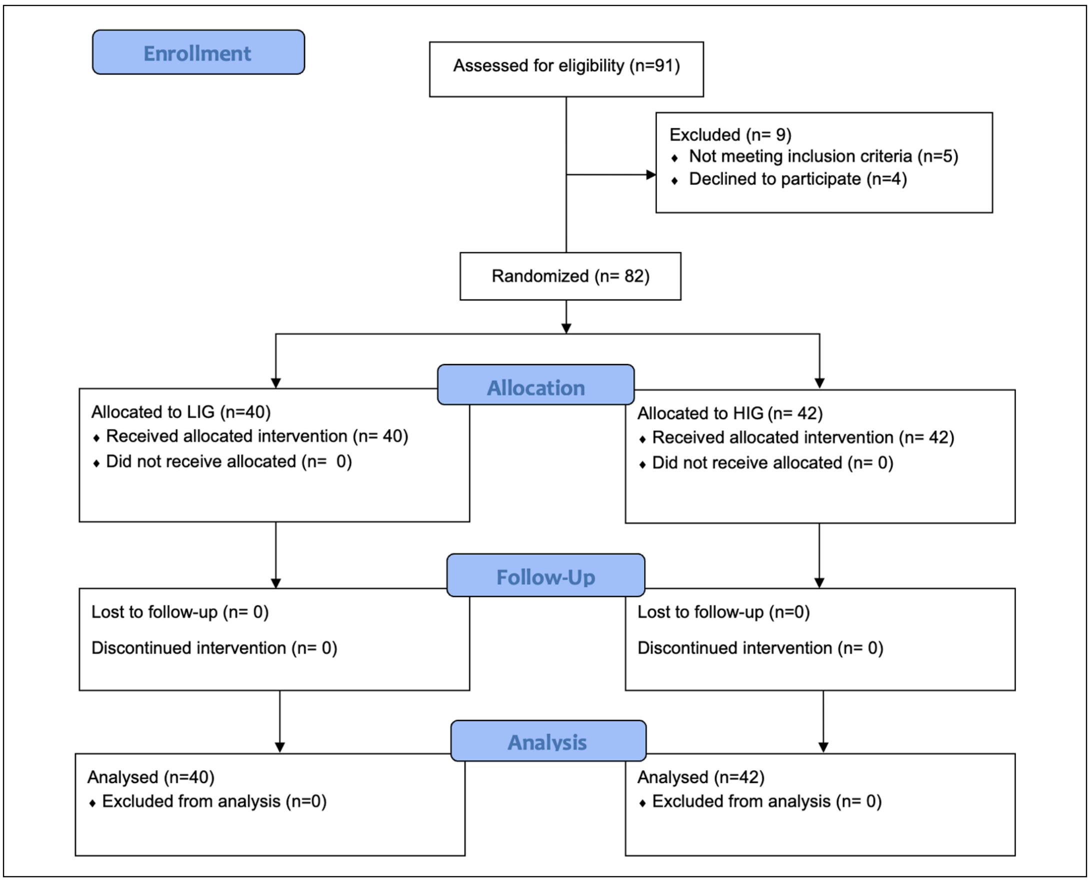

Figure 2. Flow diagram.

Table II. Within-group comparisons.

Group	Pre-treatment		Post treatment		MD	*t*	*p*	95% CI	
	Mean	SD	Mean	SD				Lower	Upper
HIG									
- Hand grip	18.48	3.57	42.60	7.01	24.12	-20.43	<.001	-26.50	-21.73
- Pinch press	6.65	0.78	10.11	0.87	3.46	-16.65	<.001	-3.88	-3.04
- STS in 60 mins	20.11	1.72	24.78	2.37	4.67	-6.14	<.001	-7.37	-6.33
- QoL	66.45	4.57	73.30	4.39	6.58	-9.33	<.001	-5.30	-4.02
LIG									
- Hand grip	17.48	2.96	23.72	2.42	6.24	-10.70	<.001	-7.42	-5.06
- Pinch press	5.9	0.59	9.48	2.27	3.58	-7.25	<.001	-3.46	-1.95
- STS in 60 mins	18.30	2.67	21.55	1.35	3.25	-5.36	<.001	-6.33	-2.86
- QoL	63.20	6.69	67.80	5.84	4.6	-7.13	<.001	-4.17	-2.32

HIG, high intensity exercises group; LIG, low intensity exercises group; STS, sit-to-stand in 60 minutes; QoL, Quality of Life.

Table III. Within and between groups comparisons using Wilcoxon and Mann-Whitney tests respectively.

Variable	Time	HIG		LIG		*U*	*p*	*d*
		M	SD	M	SD			
MPPT	Pre	18.97	1.90	19.10	1.90	803	.728	.068
	Post	27.85	2.45	24.60	2.61	319.5	<.001	1.283
MD		8.88		5.5				
Z		-5.652		-5.527				
p		<.001		<.001				

HIG, high intensity exercises group; LIG, low intensity exercises group; U, Mann-Whitney value; Z, Z statistics of Wilcoxon test; M, mean; SD, standard deviation; MPPT, modified physical performance test; d, Cohen's d value of effect size.

Table IV. Between group comparisons.

Group	Time	HIG		LIG					95% CI	
		Mean	SD	Mean	SD	*t*	*d*	*p*	Lower	Higher
Hand grip	Pre-treatment	18.48	3.57	17.48	2.96	1.38	.304	.169	-4.38	2.45
	Post treatment	42.60	7.01	23.72	2.42	16.11	3.60	<.001	16.54	21.21
Pinch press	Pre-treatment	6.65	0.78	7.18	0.54	-.820	.790	.415	-0.437	0.182
	Post treatment	10.11	0.87	9.48	2.27	1.68	.366	.097	-0.11	1.38
STS in 60 mins	Pre-treatment	20.11	1.72	18.30	2.67	1.96	.805	.053	-0.013	2.03
	Post treatment	24.78	2.37	21.55	1.35	7.52	1.67	<.001	2.38	4.09
QoL	Pre-treatment	66.45	4.57	63.20	6.69	2.91	.567	.005	1.11	5.91
	Post treatment	73.30	4.39	67.80	5.84	4.84	1.06	<.001	3.24	7.77

HIG, high intensity exercises group; LIG, low intensity exercises group; QoL, Quality of Life.

ter interventions in both groups, participants who received high-intensity exercises demonstrated higher achievements in 3 (MPPT, handgrip, STS in 30 seconds, and QoL) out of the 4 outcomes assessed in this study.

Up to the authors' knowledge, comparisons between low and high-intensity exercises have not been extensively studied in previous literature. Additionally, the response of the current study population to these exercises was not clear. Recently, Nambi et al[12] compared the effect of high *vs.* low-intensity exercises on a sample of patients having post-COVID-19 sarcopenia. Two groups each consisted of 38 participants included in the Nambi study, one of them received high-intensity aerobic training, while the other group received low-intensity aerobic exercises.

Contrary to the current findings, Nambi et al[12] reported that low-intensity aerobic exercises were more effective than high-intensity exercises at 4 and 8 weeks as well as at 6 months follow-up in favor of hand grip, strength, and quality of life. Yet, muscle mass did not show any significant difference. However, differences such as the nature of the study population, the type of exercises used, especially in the high-intensity exercises group, and the method of assessing exercise intensity could be potential reasons for these differences[12].

In another study, Stoever et al[16] compared the response of elderly obese persons with sarcopenia to those with no sarcopenia to a program of resistance training. This program, which used between 80 to 85% of maximum strength and continued for 16 weeks, resulted in significant improvements in hand grip strength (9% improvement) and MPPT (11% improvement) when compared to the baseline. Interestingly, Stoever's study found that the value of the physical function measured by the MPPT and Short Physical Performance Battery reached a level equal to the baseline values of those with no sarcopenia.

Additional support for the benefits of high-intensity resistance exercises was reported in a study conducted by Dong et al[17], a group of patients having CKD. Resistance exercises were performed in parallel with the kidney dialysis routine using the weight of the lower limbs as well as an elastic ball. After 12 weeks of training, significant improvements were observed in the maximum grip strength and physical function in favor of the high-intensity exercise group.

On the other hand, Zhou et al[36] study found that strength or balance training combined with endurance training for 12 months did not decrease sarcopenia prevalence in CKD patients[36]. In this study, the strength exercises improved overall lean body mass. Yet, it did not affect the prevalence rate of sarcopenia. It is worth noting that the outcomes of interest (plasma statin level and body fat) were quite different from those adopted in the current study.

The mechanisms by which exercise can slow down sarcopenia are complex[37]. It is well known that resistance training increases muscle mass and strength by promoting satellite cell activation and proliferation, enhancing the synthesis of muscle protein, and inhibiting muscle breakdown[38]. Sarcopenia is usually associated with a significant loss of muscle mass, which may lead to weakness and an increased risk of falls, physical disability, and poor quality of life[39]. Exercise has positive effects on muscle strength, physical function, and quality of life in people with sarcopenia[14]. Hence, it can improve the feeling of well-being and improve the patient's confidence regarding walking without fear of falling[40] which in turn reflects on improving the quality of life.

Another explanation has been introduced by Dong et al[17], which proposed that high-intensity exercises could efficiently control the status of the low-level systemic inflammation associated with CKD through the release of anti-inflammatory substances such as interleukin-6 (IL-6) and IL-10. This inflammatory condition has been linked to multiple complications usually seen in CKD, such as cardiovascular problems, protein energy expenditure, and mortality.

As presented in the current study, high-intensity resistance training should be incorporated as a part of the rehabilitation programs in populations having CKD with sarcopenia, especially those who recently recovered from COVID-19. Such exercises can reduce multiple risks, such as falling and reduced balance, and consequently improve physical functions and quality of life.

Limitations

The period of intervention, which was relatively short, represents the main limitation of the current study. Yet, this short period could be more realistic due to the nature of the participants, who usually tend to have less commitment to long-duration exercise programs in real life. Due to the low number of female participants in both groups, the sex-related variation in exercise response could not be investigated. So, the authors recommend addressing this variable in future studies.

Conclusions

High-intensity resistance exercises were superior to low-intensity aerobic training on strength, function, and quality of life in post-COVID-19 patients with sarcopenia secondary to kidney diseases.

Conflict of Interest

The authors declare that they have no conflict of interests.

Acknowledgements

The authors would like to thank all participants in this study.

Funding

This work was supported by Dr. Nasser Al-Rashid Scientific Research Chair for Renal Failure Diseases at the University of Saudi Arabia under Grant Number (SCR-22 029).

Ethics Approval

This study was conducted following the guidelines of the Helsinki Declaration from the Research Ethical Committee of the University of Hail dated 14/10/2022 (H-2022-342). Trial registration: www.clinicaltrial.gov number: NCT05593471.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Authors' Contribution

Ahmed Abdelmoniem Ibrahim, Hisham M. Hussein, and Ibrahim Metwally Dewir contributed substantially to the concept and design of the study. Shimaa T. Abu El Kasem, Mohamed Marzouk Mohamed Ragab, and Mostafa S. Abdel-fattah performed data collection. Ahmed Abdelmoniem Ibrahim and Hisham M. Hussein were responsible for the interpretation, drafting, and validation of the article. All authors gave their final approval of the version of the article to be published.

Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

ORCID ID

Ahmed Abdelmoniem Ibrahim: 0000-0002-2103-1995
Ibrahim Metwally Dewir:0000 -0002-5077-6638
Shimaa T. Abu El Kasem: 0000-0002-8375-9391
Mohamed Marzouk Mohamed Ragab: 0000-0003-4351-9737
Mostafa S. Abdel-Fattah: 0000-0001-8646-4954
Hisham M. Hussein: 0000-0003-2184-6147

References

1) Barajas-Galindo DE, González Arnáiz E, Ferrero Vicente P, Ballesteros-Pomar MD. Effects of physical exercise in sarcopenia. A systematic review. Endocrinol Diabetes y Nutr (Engl Ed) 2021; 68: 159-169.
2) Gil S, Jacob Filho W, Shinjo SK, Ferriolli E, Busse AL, Avelino-Silva TJ, Longobardi I, de Oliveira Junior GN, Swinton P, Gualano B, Roschel H. Muscle strength and muscle mass as predictors of hospital length of stay in patients with moderate to severe COVID-19: a prospective observational study. J Cachexia Sarcopenia Muscle 2021; 12: 1871-1878.
3) Bikbov B, Purcell CA, Levey AS, Smith M, Abdoli A, Abebe M, Adebayo OM, Afarideh M, Agarwal SK, Agudelo-Botero M, Ahmadian E. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2020; 395: 709-733.
4) Ali AM, Kunugi H. Screening for sarcopenia (physical frailty) in the COVID-19 era. Int J Endocrinol 2021; 2021: 1-16
5) Souza VA de, Oliveira D, Barbosa SR, Corrêa JO, Colugnati FA, Mansur HN, Fernandes NM, Bastos MG. Sarcopenia in patients with chronic kidney disease not yet on dialysis: analysis of the prevalence and associated factors. PLoS One 2017; 12: e0176230.
6) Walston JD. Sarcopenia in older adults. Curr Opin Rheumatol. NIH Public Access 2012; 24: 623-627.
7) Ibrahim AA, Althomali OW, Hussein HM, Atyia MR, Eldesoky MT, Gamal M, Abdelbasset WK. Physical and psychological response to exercise training in chronic kidney disease patients: A quasi-randomized controlled trial. Med Sci 2021; 25: 547-555.
8) Ibrahim AA, Althomali OW, Atyia MR, Hussein HM, Abdelbasset WK, Eldesoky MT, Gamal M. A systematic review of trials investigating the efficacy of exercise training for functional capacity and quality of life in chronic kidney disease patients. Int Urol Nephrol 2022; 54: 289-298.
9) Moorthi RN, Avin KG. Clinical relevance of sarcopenia in chronic kidney disease. Curr Opin Nephrol Hypertens 2017; 26: 219-228.
10) Gérard M, Mahmutovic M, Malgras A, Michot N, Scheyer N, Jaussaud R, Nguyen-Thi PL, Quilliot D. Long-Term Evolution of Malnutrition and Loss of Muscle Strength after COVID-19: A Major and Neglected Component of Long COVID-19. Nutrients 2021; 13: 3964.
11) Morley JE, Kalantar-Zadeh K, Anker SD. COVID-19: a major cause of cachexia and sarcopenia? J Cachexia Sarcopenia Muscle 2020; 11: 863-865.
12) Nambi G, Abdelbasset WK, Alrawaili SM, Elsayed SH, Verma A, Vellaiyan A, Eid MM, Aldhafian OR, Nwihadh NB, Saleh AK. Comparative effectiveness study of low versus high-intensity aerobic training with resistance training in community-dwelling older men with post-COVID-19 sarcopenia: A randomized controlled trial. Clin Rehabil 2022; 36: 59-68.

13) Sen EI, Eyigor S, Dikici Yagli M, Ozcete ZA, Aydin T, Kesiktas FN, Aydin FY, Vural M, Sahin N, Karan A. Effect of Home-Based Exercise Program on Physical Function and Balance in Older Adults With Sarcopenia: A Multicenter Randomized Controlled Study. J Aging Phys Act 2021; 29: 1010-1017.

14) Tsekoura M, Billis E, Tsepis E, Dimitriadis Z, Matzaroglou C, Tyllianakis M. The effects of group and home-based exercise programs in elderly with sarcopenia: A randomized controlled trial. J Clin Med 2018; 7: 480-498.

15) Najafi Z, Kooshyar H, Mazloom R, Azhari A. The Effect of Fun Physical Activities on Sarcopenia Progression among Elderly Residents in Nursing Homes: a Randomized Controlled Trial. J Caring Sci 2018; 7: 137-142.

16) Stoever K, Heber A, Eichberg S, Brixius K. Influences of Resistance Training on Physical Function in Older, Obese Men and Women with Sarcopenia. J Geriatr Phys Ther 2018; 41: 20-27.

17) Dong ZJJ, Zhang HLL, Yin LXX. Effects of intradialytic resistance exercise on systemic inflammation in maintenance hemodialysis patients with sarcopenia: a randomized controlled trial. Int Urol Nephrol 2019; 51: 1415-1424.

18) Kim SW, Park HY, Jung WS, Lim K. Effects of Twenty-Four Weeks of Resistance Exercise Training on Body Composition, Bone Mineral Density, Functional Fitness and Isokinetic Muscle Strength in Obese Older Women: A Randomized Controlled Trial. Int J Environ Res Public Health 2022; 19: 14554-14566.

19) Huang Y, Tan C, Wu J, Chen M, Wang Z, Luo L, Zhou X, Liu X, Huang X, Yuan S, Chen C. Impact of coronavirus disease 2019 on pulmonary function in early convalescence phase. Respir Res 2020; 21: 163-173.

20) Datar NA, Devi TP. Effect of Graded Thera-band Exercises on Shoulder Muscle Strength and Activities of Daily Life in Modified Radical Mastectomy Subjects. Biomed Pharmacol J. Biomed Pharmacol J 2019; 12: 1345-1351.

21) Law TD, Clark LA, Clark BC. Resistance Exercise to Prevent and Manage Sarcopenia and Dynapenia. Annu Rev Gerontol Geriatr 2016; 36: 205-228.

22) Chung P-K, Zhao Y, Liu JD, Quach B. A Brief Note on the Validity and Reliability of the Rating of Perceived Exertion Scale in Monitoring Exercise Intensity among Chinese Older Adults in Hong Kong. Percept Mot Skills 2015; 121: 805-809.

23) Pasini E, Lahaye SL, Flati V, Assanelli D, Corsetti G, Speca S, Bernabei R, Calvani R, Marzetti E. Effects of treadmill exercise and training frequency on anabolic signaling pathways in the skeletal muscle of aged rats. Exp Gerontol 2012; 47: 23-28.

24) Mahmoud WS, Kamel E, Atteya M, Ibrahim A, Alrawaili S, Hussein H. Immediate and short-term effects of 35% tension Kinesio taping on handgrip strength in healthy females. Physiother Q 2021; 29: 9-13.

25) Abizanda P, Navarro JL, García-Tomás MI, López-Jiménez E, Martínez-Sánchez E, Paterna G. Validity and usefulness of hand-held dynamometry for measuring muscle strength in community-dwelling older persons. Arch Gerontol Geriatr 2012; 54: 21-27.

26) Gorniak SL, Plow M, McDaniel C, Alberts JL. Impaired Object Handling during Bimanual Task Performance in Multiple Sclerosis. Mult Scler Int 2014; 2014: 1-9.

27) Squillace M, Krupp L, Ray S, Muratori LM. Pinch Strength Measurements in Adolescents With Pediatric Multiple Sclerosis. Int J MS Care 2023; 25: 30-34.

28) Yoshiko A, Ogawa M, Shimizu K, Radaelli R, Neske R, Maeda H, Maeda K, Teodoro J, Tanaka N, Pinto RS, Akima H. Chair sit-to-stand performance is associated with diagnostic features of sarcopenia in older men and women. Arch Gerontol Geriatr 2021; 96: 104463.

29) Macfarlane DJ, Chou KL, Cheng YH, Chi I . Validity and normative data for thirty-second chair stand test in elderly community-dwelling Hong Kong Chinese. Am J Hum Biol 2006; 18: 418-421.

30) Yee XS, Ng YS, Allen JC, Latib A, Tay EL, Abu Bakar HM, Ho CY, Koh WC, Kwek HH, Tay L. Performance on sit-to-stand tests in relation to measures of functional fitness and sarcopenia diagnosis in community-dwelling older adults. Eur Rev Aging Phys Act 2021; 18: 1-11.

31) Bohannon RW, Crouch R. 1-Minute Sit-To-Stand Test: Systematic Review Of Procedures, Performance, And Clinimetric Properties. J Cardiopulm Rehabil Prev 2019; 39: 2-8.

32) Addison O, Kundi R, Ryan AS, Goldberg AP, Patel R, Lal BK, Prior SJ.Clinical relevance of the modified physical performance test versus the short physical performance battery for detecting mobility impairments in older men with peripheral arterial disease. Disabil Rehabil 2018; 40: 3081-3085.

33) Beaudart C, Biver E, Reginster JY, Rizzoli R, Rolland Y, Bautmans I, Petermans J, Gillain S, Buckinx F, Dardenne N, Bruyère O. Validation of the SarQoL®, a specific health-related quality of life questionnaire for Sarcopenia. J Cachexia Sarcopenia Muscle 2017; 8: 238-244.

34) Tsekoura M, Kastrinis A, Katsoulaki M, Billis E, Gliatis J. Sarcopenia and its impact on quality of life. Adv Exp Med Biol 2017; 987: 213-218.

35) Witham MD, Heslop P, Dodds RM, Clegg AP, Hope SV, McDonald C, Smithard D, Storey B, Tan AL, Thornhill A, Sayer AA.Performance of the SarQoL quality of life tool in a UK population of older people with probable sarcopenia and implications for use in clinical trials: findings

from the SarcNet registry. BMC Geriatr 2022; 22: 368-378.

36) Zhou Y, Hellberg M, Hellmark T, Höglund P, Clyne N.Muscle mass and plasma myostatin after exercise training: a substudy of Renal Exercise (RENEXC)—a randomized controlled trial. Nephrol Dial Transplant 2021; 36: 95-103.

37) Lazarus NR, Harridge SDR. Declining performance of master athletes: silhouettes of the trajectory of healthy human ageing? J Physiol 2017; 595: 2941-2948.

38) Johnston APW, De Lisio M, Parise G. Resistance training, sarcopenia, and the mitochondrial theory of aging. Appl Physiol Nutr Metab 2008; 33: 191-199.

39) Mielgo-Ayuso J, Fernández-Lázaro D. Sarcopenia, exercise and quality of life. Int J Environ Res Public Health 2021; 18: 6-9.

40) Pijnappels M, Van der Burg JC, Reeves ND, van Dieën JH. Identification of elderly fallers by muscle strength measures. Eur J Appl Physiol 2008; 102: 585-592.