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Effectiveness of Intradialytic Resistance Training on Muscle Mass and Strength in Patients on Hemodialysis

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Abstract

Hemodialysis (HD) patients with chronic kidney disease (CKD) lose muscle mass and strength due to protein energy wasting (PEW). The purpose of this study was to test the effectiveness of intradialytic resistance training (IRT) in increasing muscle mass and strength. It used a pre-experimental, one-group pretest-posttest design. Based on a sample size estimate using G*power software, 33 CKD patients undergoing HD at a private hospital in Bali were included. The patients were selected using purposive sampling. Muscle mass was measured using Bioelectrical Impedance Analysis (BIA), while muscle strength was measured using the Medical Research Council Muscle Scale. The Wilcoxon test evaluated IRT's efficacy on muscle strength, while the dependent samples t-test evaluated its impact on muscle mass. The results of this study found that IRT had no effect on muscle mass, with a mean difference of -0.330 (p = 0.274). On the contrary, IRT significantly improved muscle strength (p = 0.018). In conclusion, IRT proved beneficial for strengthening muscle but not for gaining muscle mass. Therefore, to improve muscle strength, patients with CKD undergoing HD are advised to actively perform IRT under supervision for a minimum of 30 minutes per day.

Keywords: intradialytic resistance training, muscle mass, muscle strength, protein energy wasting

Abstrak

Efektifitas* Intradialytic Resistance Training *Terhadap Massa dan Kekuatan Otot Pasien dengan Hemodialisis. *Pasien hemodialisis* (HD) *dengan Penyakit Ginjal Kronis* (PGK) *kehilangan massa dan kekuatan otot yang disebabkan oleh* Protein Energy Wasting (PEW). *Tujuan penelitian ini adalah untuk menguji efektifitas* Intradialytic Resistance Training (IRT) *terhadap peningkatan massa dan kekuatan otot. Penelitian ini menggunakan* pre-experimental one-group pretest, post-test design. *Berdasarkan perhitungan besar sampel menggunakan* G*Power Software, 33 *pasien* PGK *yang menjalani* HD *di sebuah rumah sakit swasta di* Bali *terlibat dalam penelitian ini. Pasien dipilih menggunakan teknik* purposive sampling. *Massa otot diukur menggunakan* Bioelectrical Impedance Analysis (BIA), *sedangkan kekuatan otot menggunakan* Medical Research Council Muscle Scale. *Uji efektifitas kekuatan otot menggunakan* Wilcoxon test, *sedangkan* t-test *digunakan untuk menguji efektifitas massa otot. Hasil penelitian menunjukan* IRT *tidak efektif dalam meningkatkan massa otot, dengan* mean *-0,330 (p = 0,274). Namun,* IRT *terbukti efektif dalam mening-katkan kekuatan otot, (p = 0,018). Kesimpulannya,* IRT *bermanfaat untuk meningkatkan kekuatan otot, tetapi tidak untuk meningkatkan massa otot. Oleh karena itu, untuk meningkatkan kekuatan otot, pasien* PGK *yang menjalani* HD *disarankan aktif melakukan* IRT *dengan pengawasan minimal* 30 *menit dalam sehari.*

Kata Kunci: intradialytic resistance training, *kekuatan otot, massa otot,* protein energy wasting

Introduction

Protein energy wasting (PEW) ranges from 20––80% in hemodialysis patients with chronic kidney disease (CKD) (Chen et al., 2013). PEW contributes to morbidity and mortality, especially among CKD patients. PEW results from various mechanisms that occur in patients with CKD, such as malnutrition, systemic inflammation, comorbidities, hormonal disorders, dialysis procedures, and other consequences of uremic toxicity (Radjen et al., 2018). PEW syndrome is a simultaneous loss of body protein and energy reserves, contributing to decreased muscle mass in patients with CKD on hemodialysis (HD) and negatively impacting muscle strength (Cheng et al., 2022).

Decreased muscle mass can lead to reduced physical activity, impaired muscle function, a lower quality of life, an increased risk of hospitalization, and falls. Several factors contribute to a decrease in muscle mass in patients with CKD on HD. First, protein intake decreases as CKD progresses. Second, fluid restrictions can cause a simultaneous decrease in calorie intake (Bakaloudi et al., 2020). Inadequate food intake leads to malnutrition associated with PEW syndrome in patients with CKD (Cheng et al., 2022). A private hospital in Bali conducts monthly malnutrition assessments of patients on HD, but it does not yet conduct assessments of their muscle mass. The researchers hope that, like malnutrition, muscle mass will be routinely assessed in patients on HD because decreased muscle mass is associated with decreased survival (Radjen et al., 2018).

Besides decreased food intake, the third factor causing decreased muscle mass in patients with CKD on HD is the HD procedure, which contributes to increased catabolic status, causing decreased protein synthesis and increased proteolysis. The fourth is catabolic factors, such as acidosis, comorbidities, inflammation, corticosteroid use, and a sedentary lifestyle (Bakaloudi et al., 2020). In addition, HD has direct side effects, primarily related to the time required for HD therapy; during HD therapy, the patient is in a sitting or supine position for 4–5 hours with little or no physical activity, which occurs 2–3 times a week, and they have dietary restrictions. Furthermore, food causes the patient to reduce their physical activity, contributing to a decline in their function. Functional decline in patients on HD can be minimized by implementing specific exercise programs during HD therapy (Cheng et al., 2022).

Intradialytic exercise is a typical recommendation to encourage patients to be physically active (Young et al., 2018). Intradialytic resistance training (IRT) effectively prevents functional muscle loss in patients on HD (Hendriks et al., 2019). Kato et al. (2021) showed that IRT changed patients' physical performance and increased their body weight, but through increased fat mass, not muscle mass. Zelko et al. (2022) showed that IRT did not significantly affect muscle strength in the trained muscles, but this contrasts with Lopes et al. (2019), who showed that IRT increased mus-cle mass and muscle strength. These studies reported inconsistent results regarding the effectiveness of IRT in increasing muscle mass and strength in patients with CKD on HD. There has been scarce research on IRT in Indonesia.

Sulistyaningsih (2014) assessed an exercise program involving patients performing individual movements for 30 minutes twice a week for four weeks. Wodskou et al. (2021) examined motivation, barriers, and suggestions for intradialytic exercise in nurses and patients on HD. Their results showed that patients were motivated by the expected benefits of intradialytic exercise, such as better activity levels and improved quality of life. However, concerns about machine alarms dominated patient barriers. Dialysis disturbs nurses and protects needles and fistulas. In contrast, nurses are generally concerned about patient safety and recommend further study regarding the feasibility and efficacy of intradialytic exercise interventions over time.

Related research on the effect of intradialytic training on muscle mass and strength has provided inconsistent results. Therefore, it requires further investigation regarding its feasibility and efficacy, which has not been widely examined in Indonesia. Researchers are interested in examining the effectiveness of IRT in increasing muscle mass and strength in patients with CKD on HD. This study was conducted at a private hospital in Bali based on IRT guidelines implemented at one hospital in Japan.

Methods

A pre-experimental study with a one-group pretest and posttest design was conducted at a private hospital in Bali and involved 33 patients with CKD on HD. The required sample size was calculated using G*Power software with a 5% error margin and 85% confidence level. Patients were selected by purposive sampling.

The inclusion criteria were: 1) willingness to participate; 2) undergoing HD at a private hospital in Bali at least twice a week. The exclusion criteria were: 1) unstable heart status (e.g., angina, decompensated congestive heart failure, stenosis severe arteriovenous, and uncontrolled arrhythmia); 2) physical limitations (unable to mobilize); 3) installation of HD access < 3 months ago; 4) any uncontrolled medical condition, including recent (within eight weeks) infection, fever, myocardial infarction, or undiagnosed chest pain; 5) hypertension or other disorders that could be made worse by physical activity, a resting systolic blood pressure of more than 200 mmHg or a resting diastolic blood pressure of more than 110 mmHg; 6) recent systemic or pulmonary embolism, suspected or confirmed aneurysm, current or suspected myocarditis or pericarditis, or thrombophlebitis; 7) symptomatic hyper- or hypo-tension; 8) excessive inter-dialytic weight gain, which has a severe impact on fluid retention indices; 9) dehydration or feeling unwell in patients with diabetes and a current blood glucose level of > 16.7 mmol/L (300 mg/dL) and in those who are in a state of ketosis. Two patients dropped out because they could not follow all IRT guidelines and could not perform IRT twice in one week. Data collection was conducted from October to December 2022.

Bioelectrical impedance analysis (BIA) is an anthropometric tool that measures muscle mass. This study performed BIA using the Tanita BC-418MA Segmental Body Composition Analyzer; muscle mass is shown in kg units and categorized as low, average, and high according to the results of the Tanita BC-418MA analyzer. The muscle strength examination form based on the Medical Research Council Muscle Scale was used to measure muscle strength on a 0–5 scale, with categories of sufficient (score = 3), good (score = 4), and average (score = 5). The study used IRT Guide Use guidelines from the Department of Hemodialysis, Koujukai Rehabilitation Hospital. The Thera-Band resistance band was used to provide a medium load during IRT. IRT was led by researchers trained by physiotherapists and was conducted according to the patient's HD schedule. Researchers also used questionnaires to collect patients' characteristics, including their name, age, sex, education level, and employment, and a checklist form for implementing IRT. Participants performed IRT for 30 minutes during the first two hours of HD twice weekly for eight weeks.

Data analysis was conducted using SPSS (version 25). Univariate analysis was conducted to determine the minimum, maximum, mean, frequency, and proportion for each variable. The normality of the data was assessed using the Shapiro–Wilk test. Bivariate analysis was conducted for muscle mass using the dependent samples t-test and for muscle strength using the Wilcoxon rank-sum test. Bivariate analysis was also conducted to assess the effect of IRT on muscle mass and strength in patients with CKD on HD.

Data were collected after obtaining the patient's informed consent. This study was ethically approved by the Ethics Commission of the Bali Institute of Technology and Health (approval number: 04.0532/KEPITEKES-BALI/X/2022; approval date: October 4, 2022).

Results

This study was conducted from October to December 2022. It included 33 patients who met the study criteria, could follow all IRT guidelines, and could routinely perform IRT twice weekly for eight consecutive weeks. Table 1 shows the participants' general characteristics. Most were aged 15–64 years (n = 27; 84.8%), male (n = 26; 78.8%), had a high school education (n = 17; 51.5%), and currently working (n = 17; 51.5%).

Table 2 shows participants' muscle mass and strength changes from before to after IRT. Participants' muscle mass and strength increased after IRT, with mean muscle mass increasing from 44.53 to 44.86 and muscle strength from 4.48 to 4.82. Table 3 shows the results of the dependent samples t-test on the effect of IRT on muscle mass in patients with CKD on HD. The mean difference was -0.330 (standard deviation = 0.297; 95% CI = -0.935-0.275; df = 32; p = 0.274). Therefore, IRT does not effectively increase muscle mass in patients with CKD on HD.

Table 4 shows the results of the Wilcoxon rank-sum test on the effect of IRT on muscle strength in patients with CKD on HD. One participant had a negative rank change (de-creased muscle strength after IRT), eight had a positive rank change (increased muscle strength after IRT), and 24 had no rank change (un-changed muscle strength) after IRT (p = 0.018). Therefore, IRT effectively increases muscle strength in patients with CKD on HD.

Figure 1 shows participants' BIA-based muscle mass categories before and after IRT. The participants showed changes in muscle mass after IRT. Those with low muscle mass decreased from 11 (33.3%) to 6 (18.2%), those with average muscle mass increased slightly from 17 (51.5%) to 19 (57.6 %), and those with high muscle mass increased slightly from 5 (15.2%) to 8 (24.2%).

Figure 2 shows participants' muscle strength categories before and after IRT based on the Medical Research Council Muscle Scale. Those with Sufficient muscle strength decreased from 4 (12.1%) to 0 (0%), those with good muscle strength decreased from 9 (27.2%) to 6 (18.2%), and those with average muscle strength increased from 20 (60.6%) to 27 (81.8%).

Table 1. Participants' General Characteristics

Characteristic	N	%
Sex		
Male	26	78.8
Female	7	21.2
Age (years)		
Productive (15–65)	27	84.8
Non-productive (> 65)	6	15.2
Education level		
No School	2	6.1
Junior high school	4	12.1
Senior high school	17	51.5
College	10	30.3
Occupation		
Employed	17	51.5
Non employed	16	48.5

Table 2. Participants' Muscle Mass and Strength Before and After IRT

Variable	Before				After				N
	Min	Max	Mean	SD	Min	Max	Mean	SD	
Muscle Mass	29	67	44.53	9.56	27	68	44.86	9.802	33
Muscle Strength	3	5	4.48	0.712	4	5	4.82	0.392	33

Table 3. Dependent Sample T-test of the Effect of IRT on Muscle Mass

Muscle Mass	Mean	SD	SE	95% CI	t	df	p
Before and after IRT	-0.330	1.706	0.297	(−0.935–0.275)	−1.112	32	0.274

Table 4. Wilcoxon Rank-Sum Test of the Effect of IRT on Muscle Strength

		Rank			Test statistic	
		N	Mean rank	Sum of ranks		
Before and after IRT	Negative rank	1a	3.00	3.00	z	−2.373b
	Positive rank	8b	5.25	42.00	p-value	0.018
	Tie	24c				
	Total	33				

Figure 1. Participants' muscle mass category before and after IRT

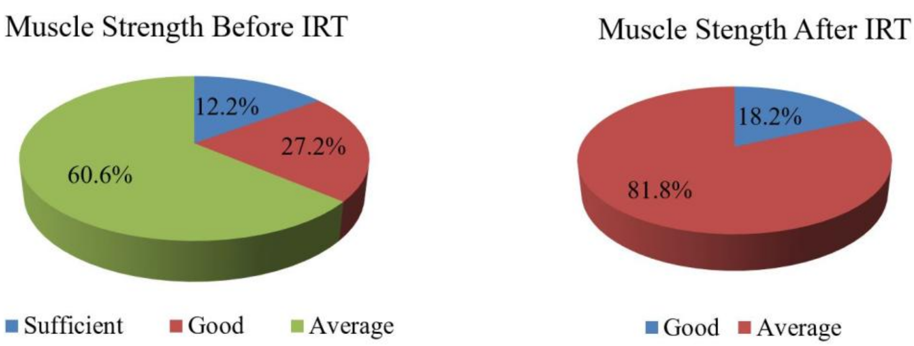

Figure 2. Participants' muscle strength category before and after IRT

Discussion

In this study, most participants had average muscle mass before IRT (n = 17), followed by low muscle mass (n = 11). The condition of nutrition and body composition, particularly muscle mass, are closely related to morbidity, mortality, and quality of life in patients with CKD on HD (Visser et al., 2020). A cross-sectional study by Yohan et al. (2020) showed a positive correlation between muscle mass and the quality of life in patients with CKD on HD. A prospective and longitudinal study by Visser et al. (2020) showed that the average patient with CKD on HD experienced a substantial decrease in muscle mass (-6.4 kg in 20 weeks or -1.3 kg/month). Loss of muscle mass is faster in male patients, related to the inflammation response. Theoretical explanations for the sex difference in muscle mass loss are testosterone's anabolic effects and estrogen's anti-inflammatory effects. This research reinforces the need for regular body composition checks to determine muscle mass.

Decreased muscle mass can be reversed with exercise. However, patients on HD typically have low activity levels, possibly due to the time burden and symptoms associated with their treatment (Lambert et al., 2022). A systematic review and meta-analysis showed that the effectiveness of exercise on physical function and quality of life in patients with CKD on HD was as follows. First, while patients on dialysis have a high-risk status, there are no severe side effects related to exercise, such as post-exercise hypotension, fatigue, myalgia, leg pain, and worsening leg ulcers (Parker, 2016). Adherence to exercise programs ranged from 43% to 100%, and dropout rates from programs range from 15% to 50% (Ashby et al., 2019; Wodskou et al., 2021; Yuguero-Ortiz et al., 2021).

Second, short-term exercise (2–6 months), regardless of type, frequency, and intensity, produced clinically significant and moderate/considerable improvements in cardiorespiratory fitness, with an average increase in peak oxygen consumption rate of 5 mL/kg/minute (Parker, 2016; Yuguero-Ortiz et al., 2021). Third, any exercise prescribed during an HD session resulted in clinically significant and moderate increases in muscle strength (Castro et al., 2021; Greenwood et al., 2020; Parker, 2016). Fourth, any prescribed exercise consistently produced clinically significant and considerable improvements in several functional capacity indices (Valenzuela et al., 2018; Yabe et al., 2021; Zhang et al., 2020). Finally, self-reported physical function improved significantly in patients who exercised, often contributing to improved quality of life scores (Greenwood et al., 2020; Zhang et al., 2020).

Our results showed that IRT was ineffective in increasing muscle mass in patients with CKD on HD, consistent with Kato et al. (2021). However, this finding differs from Sulistyaningsih (2014), who showed differences in the leg muscles in the treatment group after physical exercise. This difference might reflect differences in the procedures for implementing IRT; our study used the same IRT procedures as Kato et al. (2021), while Sulistyaningsih (2014) used an IRT procedure in which participants performed movements independently for 30–45 minutes.

The difference in results may be explained as follows: while sports training in various program types is a potent stimulus to increase muscle mass in various pathologies and helps fight factors causing muscle wasting (Graham et al., 2021), several factors cause muscle mass loss in patients with CKD on HD. First, in CKD progression, there is a decrease in protein intake and anorexia, which is reported to occur in about one-third of patients on HD. Second, fluid restriction can cause a simultaneous decrease in calorie intake. Third, the HD procedure may contribute to a catabolic state due to decreased protein synthesis and increased proteolysis. Fourth, catabolic factors cause mass muscle loss in patients on HD, including acidosis, comorbidities, inflammation, cortico-steroid use, and a sedentary lifestyle (Bakaloudi et al., 2020; Koppe et al., 2019; Radjen et al., 2018).

Recent studies have shown that the HD process affects energy and protein homeostasis. Protein loss during dialysis sessions combined with low nutrient intake results in low nutrient availability for muscle synthesis (Radjen et al., 2018). Nutritional status, catabolic status, and hormonal factors influence muscle mass. Since muscle mass regulation involves complex biochemical interactions, imbalances significantly affect protein homeostasis (Radjen et al., 2018). Researchers have realized that treating muscle mass loss, such as with IRT, is insufficient for physical activity. However, consideration is also needed in providing therapies that help address factors influencing muscle mass, such as controlling nutritional status, catabolic status, and hormonal status (e.g., insulin resistance), with nutritional supplements and supplements to treat metabolic acidosis (Graham et al., 2021).

Most participants showed Average muscle strength before IRT (n = 20). Muscle mass is closely correlated with muscle function. A prospective study showed that the decline in muscle function was greater than the loss of muscle mass (Koo, 2022). Graham et al. (2021) showed that skeletal muscle mass reduced by 20%–30%, and strength reduced by up to 40%. Muscle strength is one of the most important determinants of physical function for maintaining daily living activities in patients with CKD (Chen et al., 2023). Patients with HD have lower functional capacities, including daily living activities, as a result of reduced muscle mass and strength, which lowers their quality of life (Zhang et al., 2020).

Our study revealed that IRT was effective in improving muscle strength in patients with CKD on HD, consistent with previous studies (Castro et al., 2021; Lopes et al., 2019; Sulistyaningsih, 2014). Rhee and Kalantar-Zadeh (2014) showed that increasing physical activity could address decreased muscle mass and strength in patients with CKD on HD. Structured exercise interacts with several molecular systems that are beneficial for improving contractile function and metabolism (Greenwood et al., 2021; Myers et al., 2021). Structured exercise activates pro-anabolic signaling path-ways, converging on mechanistic target of rapamycin complexes 1/2 (mTORC1/2) to increase ribosome initiation and increase efficiency in protein synthesis. Activation of mTORC1/2 and anabolic pathways helps inhibit the activetion of transcription factors causing muscle atrophy (e.g., the forkhead box O [FOXO] family) by preventing excess protein degradation. Exercise can create long-term changes in the epigenetic profile of muscles, inducing deoxyribonucleic acid (DNA) hypermethylation in the promoter regions of deleterious genes to reduce their expression and DNA hypomethylation in regions regulating beneficial genes to increase their expression, improving neuromascular function, and helping to protect and increase muscle strength (Graham et al., 2021).

Each dialysis session should include at least 30 minutes of supervised moderate-intensity exercise for all patients with CKD on HD without contraindications, according to the Kidney Association Clinical Practice Guidelines in Hendriks et al. (2019). They also say that when they do not get dialysis, individuals with CKD should be encouraged to exercise. Apart from time, an important factor that determines an exercise's ability to assist muscle maintenance is its kind. Exercise during (intradialytic) or in between (interdialytic) HD sessions is one way that patients with CKD on HD might receive physical activity intervention (Arazi et al., 2022).

In patients with CKD on HD, a meta-analysis found no difference in the effectiveness of intradialytic exercise compared to interdialytic exercise in terms of improving physical function (Hendriks et al., 2019). However, patients with CKD do not adhere well to long-term supervised physical activity intervention programs because of exercise intolerance. Patients with CKD can incorporate supervised physical exercise into their weekly regimen by participating in HD sessions. Compared to interdialytic physical activity, intradialytic physical exercise is safer and exhibits higher compliance. A patient-specific exercise program can also be created by monitoring intradialytic exercise sessions; progressive, resistance-type workouts are thought to be the most efficient in building muscle mass and strength (Arazi et al., 2022; Yuguero-Ortiz et al., 2021).

This study had strengths and weaknesses. Its strength is that IRT research is rarely conducted in Indonesia, and our findings provide updates on the care of patients on HD in Indonesia. Its limitations were its small sample of no randomly chosen patients, lack of a control group, and inclusion of only one intradialytic exercise in the IRT intervention (resistance training).

Conclusion

IRT was effective in increasing muscle strength but ineffective in increasing muscle mass. With abundant benefits and minimal side effects, IRT has preventive implications for fighting muscle wasting. Therefore, it is highly recommended that CKD patients conduct IRT, either during HD sessions or on non-HD days. Future studies should include a larger sample and a control group.

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