

Original Research

The Effect Of Hand Exercise On Grip Strength, Forearm Circumference, Diameter Of Vein, Blood Flow Volume And Velocity In Patient Who Underwent Arteriovenous Fistula Surgery And On Routine Haemodialysis

Jufri Febriyanto Poetra¹, Andriati¹, Dewi Poerwandari¹

¹Physical Medicine and Rehabilitation Department, Airlangga University, Surabaya, Indonesia.

Abstract

Background: The arteriovenous fistula (AVF) is considered the gold standard for haemodialysis access. The fistula needs time to be mature and functional. Maturation process respond to increases in blood flow. Exercise stimulates vascular response as such an increase of blood flow.

Aims: The purpose of this study is to determine the effectiveness of hand exercise in increasing grip muscle performance, and its effectiveness in supporting maturation process of fistula.

Methods: This experimental study done on 14 patients underwent AVF procedure and on routine haemodialysis. Randomly, 7 subjects allocated on intervention group by doing hand exercise using hand gripper (HG) for 5 weeks, and 7 subjects allocated as control group without introduction to hand gripper. Grip strength and forearm circumference were measured before and after 5 weeks of intervention. Cephalic vein diameter, blood flow volume and velocity were measured using Doppler USG on AVF arm. The comparison of intervention effects between groups treatment were analyzed based on effect size (ES).

Results: Grip strength and forearm circumference increased significantly on intervention group before and after exercise intervention ($p < .001$, $p = .001$). Cephalic vein diameter and blood flow were increased significantly in this group ($p = .027$, $p = .033$). Blood flow velocity showed no difference before and after exercise intervention. Significant results were found on increased grip strength, forearm circumference, cephalic vein diameter and blood flow volume in comparison between treated group ($p < .001$; $ES = .94$, $p < .001$; $ES = .4$, $p = .046$; $ES = .84$, $p = .035$; $ES = .53$). There were no differences on cephalic vein blood flow velocity between these two groups.

Conclusion: Five weeks hand exercise were effective to increase grip strength, forearm circumference, cephalic vein diameter and blood flow volume, nonetheless ineffective to increase cephalic vein blood flow velocity in post AVF procedure patients with routine haemodialysis.

Keywords: *hand exercise, arteriovenous fistula, fistula maturation, cephalic vein, grip strength, chronic renal failure, haemodialysis.*

Introduction

The establishment of permanent vascular access has been recognized as one of the most important factor in the rapid growth and success of haemodialysis as a form of end stage renal failure treatment.¹

The advantage of Arteriovenous Fistula (AVF) has been approved as one of permanent vascular access, nonetheless it takes time for fistula to be mature and functional. Maturation is known to occur in response to increases in blood flow. The maturation failure will decrease the patency rates of AVF.² Some researchers reported decreased hand function in patients with AVF, specifically on impairment of muscle performance due to immobilization, neuromuscular breakdown, and AVF procedure complication.²⁻⁵

Physical exercise and muscle contraction are the potent stimulus on changes of vascular structure. Increase of blood flow through the vessel will increase shear stress which is the main stimulus in enlargement of vessel diameter.⁶ Hand exercise proved effective in increasing vasodilation and fistula maturation, thus decrease mortality rate after AVF procedure.^{3-5,7,8}

The purpose of this study is to determine the effectiveness of 5 weeks hand exercise in improving grip muscle performance by measurement of grip strength and forearm circumference, and in improving fistula maturation process by measurement of the changes of vessel diameter, blood flow volume and velocity, before and after intervention in post AVF procedure patient who had routine haemodialysis.

Material and Methods

Design

This study was a quasi-experimental study using randomized pretest and posttest control group design. This study was held on Physical Medicine and Rehabilitation clinic in Dr. Soetomo Hospital Surabaya, Indonesia.

Participants

Between July and November 2015, fourteen patients (aged 30-60 years; 10 males, 4 females) who were diagnosed with chronic kidney disease (CKD) by Nephrologist from Nephrology Department at Dr. Soetomo Hospital were included in the study. Each patient had undergone an AVF surgery procedure in the upper limb (fistula age 2-8 months) and on routine haemodialysis once or twice weekly, 4-5 hours per session at Dr. Soetomo hospital Surabaya, Indonesia. Patient with specific signs and symptoms of radiculopathy or peripheral neuropathy, and hemiparesis on AVF limb assessed from physical examination were excluded. The inclusion of patients with cardiovascular disorders, myopathy, and any type of arthritis that could affect the study results was also limited. The patients were randomly allocated into two groups, 7 subjects allocated in intervention group, which treated to do hand exercise using hand gripper (HG) for 5 weeks, and the other 7 subjects allocated as a control group that received routine care without introduction of a hand gripper.

The study was approved by the Ethics Committee, and written informed consent was obtained from all patients after they had been duly informed of the nature of the study.

Exercise protocol

The subjects in the intervention group received hand exercise prescription using hand gripper (Siken® Manufacture, Taiwan) (Figure 1a & 1b).

The subject set their hand grip resistance at 10 repetition maximum (RM), and performed 10 squeezes for 1 set. They performed 3 sets of 10 squeezes each at a 1-minute interval. Three sets of exercises were performed 2 times in the morning and 2 times in the afternoon. Resistance of Hand Gripper (HG) was reset to 10 RM every two week when the subjects visited our out-patient department.

All of the subjects were monitored for any signs of infection, abscess formation, inflammation, dehiscence, pain or tenderness causing limitation of motion in the operated limb during 24 hours after the AVF surgery. Thrill weakening on AVF also were observed. If these abnormal signs were not detected during 24 hours, they immediately started the hand-squeezing exercise. Subjects performed the exercise for 5 weeks.

The patient's family took a role in supervising the compliance to do the exercise at home. Subjects received checklist sheet to be filled and approved by a member of family who supervised them after every training session.

Measurement of grip strength and forearm circumference

The measurement procedure performed in the examination room with controlled

temperature (25-28°C) in the morning. We used digital hand dynamometer (CAMRY EH101 - Camry Co., CA, USA) for measuring the grip strength and metric tape (KaiRui - Guangzhou, China) for measuring the forearm circumference (Figure 2a & 2b).

For the grip strength measurement, the subjects were asked to sit on a chair with their hip joint flexed at 90°, and shoulder joint in a neutral position. The elbow was fixed at 90° flexion, forearm in mid position (Figure 3). Subjects were asked to squeeze the dynamometer as strong as they could. The test was performed twice, and the higher value between the two measurements was selected. Subjects were allowed a rest time of more than 5 minutes after the first measurement to avoid examiner bias and to decrease physical stress.

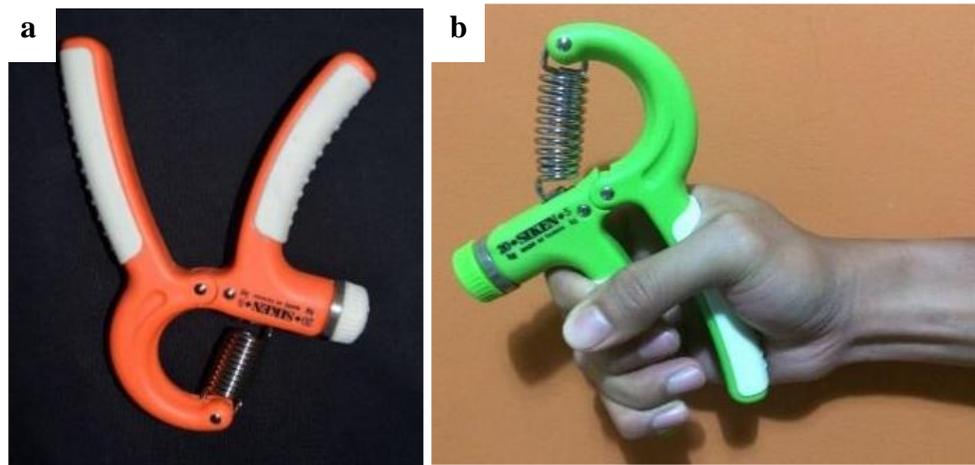


Figure 1. [a] Weight adjustable hand gripper instrument (Siken® Manufacture, Taiwan), [b] Instrument position while in exercise.

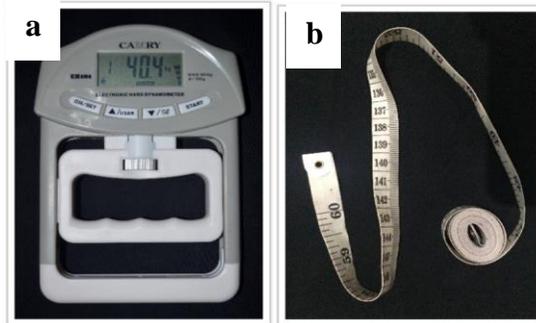


Figure 2. [a] Digital hand dynamometer (CAMRY EH101 – Camry Co., CA, USA), [b] Metric tape measure (KaiRui – Guangzhou, China).

For the forearm circumference measurement, subjects were seated on a chair with their forearm supinated, and the elbow flexed at 90°. Circumference of the forearm was measured 3 cm distal to the cubital fossa (Figure 4).

The grip strength and forearm circumference were measured by the same examiner before beginning the hand-squeezing exercise and 5 weeks after the exercise.

Examination of the cephalic vein

The cephalic vein in the AVF arm side was examined by an experienced technician

from Radiology Department in Dr. Soetomo hospital with Doppler ultrasonography (USG). A single technician performed ultrasonography during the whole study, and he was not aware of the group to which the subjects were allocated. Ultrasonography of the cephalic vein was performed before beginning the exercise and after completing the 5-week training. The technician examined the vein from the AVF site to the proximal area until he could identify the vein on the image. The diameter, blood flow volume, and blood flow velocity were measured at 3-4 cm proximal from AVF (Figure 5).



Figure 3. Position of the patient while performing grip strength measurement with hand dynamometer.



Figure 4. Metric tape placement for measuring forearm circumference.

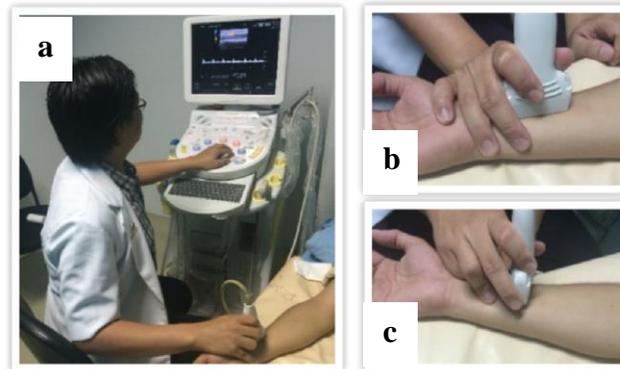


Figure 5. [a] Cephalic vein examination by experienced technician using Doppler ultrasonography (HI VISION Preirus – Hitachi Med. Co., Japan), [b] Longitudinal position of USG probe, [c] Axial position of USG probe.

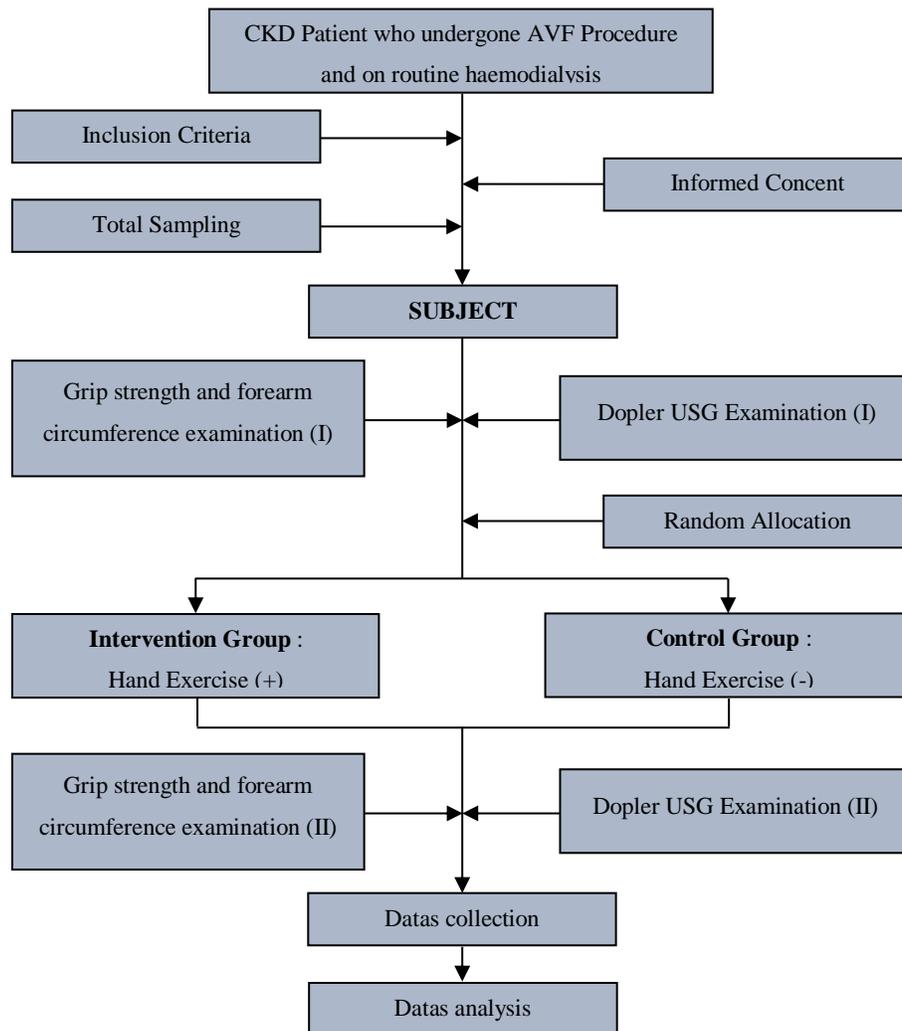


Figure 6. Flowchart of current study

Statistical Analysis

SPSS ver. 23.0 for Windows was used for statistical analysis. The *p*-values less than .05 were considered statistically significant. Comparison between pre- and post-exercise in each group was analyzed using paired t-test when data had a normal distribution and homogen. Vice versa, Wilcoxon signed-rank test was used when data did not distributed normally.

We used independent t-test to compare between the intervention group and control group. For statistical analysis between the groups, Gain Score measurement was used. Gain score was calculated based on the difference between pre- and post-exercise value.

$$\text{Gain Score} = \text{Post exercise Value} - \text{Pre exercise Value}$$

The magnitude of the exercise intervention effect was determined by utilizing change scores in the calculation of Effect Size (ES) with values of .20, .50, and .80 indicating small, medium and large effects, respectively.

Result

Comparison analysis of exercise effects

Intervention group

In the intervention group, before the exercise prescription, grip strength was 25.91±5.61 kg and forearm circumference was 22.21±2.17 cm. The diameter of cephalic vein was 5.04±.48 mm, blood flow velocity was 87.14±13.39 cm/s, and blood flow volume was 487.57±58.25 mL/min.

After 5-week exercise program, grip strength was elevated to 31.35±5.24 kg and forearm circumference increased to 23.18±2.33 cm. The diameter of cephalic vein increased to 5.48±.73 mm, blood flow velocity was increased to 95.14±16.57 cm/s, and blood flow volume was elevated to 506.57±57.89 mL/min.

There were significant differences in grip strength, forearm circumference, cephalic vein diameter, and blood flow volume after 5-week exercise ($p<.05$), except blood flow velocity ($p=.68$) (Table 2).

Control group

In the control group, before the exercise prescription, grip strength was 24.05±5.39 kg and forearm circumference was 21.21±1.72 cm. The diameter of cephalic vein was 4.93±.64 mm, blood flow velocity was 93±14.19 cm/s,

and blood flow volume was 495.43±66.26 mL/min.

After 5-week exercise program, grip strength was elevated to 24.44±5.24 kg and forearm circumference increased to 21.38±1.64 cm. The diameter of cephalic vein increased to 5.23±.37 mm, blood flow velocity was increased to 99.86±21.48 cm/s, and blood flow volume was elevated to 506.43±80.95 mL/min.

The increment of all parameters value in control group did not reach the statistical significance level ($p<.05$)(Table 3).

Comparison analysis between two groups

Gain Score (GS) analysis was used in the grip strength, forearm circumference, and sonography vascular measurements for comparing between intervention group and control group. The magnitude of exercise intervention effect was determined by calculating the Effect Size (ES) based on Coehen-D coefficient (d value)(Table 4).

Intervention group showed a Gain Score of 5.44±.58 in the grip strength, .97±.39 in the forearm circumference, .61±.53 in the diameter of cephalic vein, 8±9.52 in blood flow velocity, and 21±20.12 in the blood flow volume.

Control group demonstrated a Gain Score of .38±.46 in the grip strength, .17±.19 in the forearm circumference, .13±.18 in the diameter of cephalic vein, 6.86±9.53 in blood flow velocity, and 11±17.33 in the blood flow volume.

Table 1. Baseline characteristics of subjects

	Intervention Group	Control Group	P value
	Mean ±SD	Mean ±SD	
Case (male:female)	7 (5:2)	7 (5:2)	1.00
Age (yrs)	46 ± 7.49	45.86 ± 6.25	0.90
Body weight (kg)	65.85 ± 5.27	66.71 ± 4.34	0.74
Body height (cm)	165.14 ± 3.97	165.14 ± 2.85	1.00
Fistular age (mos)	4.57 ± 2.22	5.14 ± 2.03	0.62

Table 2. Comparison of parameters change before and after exercise in the intervention group

Parameters	Intervention Group (n=7)		P value
	Before exercise	After exercise	
Grip strength (kg)	7 (5:2)	7 (5:2)	1.00
Forearm circumference (cm)	46 ± 7.49	45.86 ± 6.25	0.90
Cephalic vein diameter (mm)	65.85 ± 5.27	66.71 ± 4.34	0.74
Blood flow velocity (cm/s)	165.14 ± 3.97	165.14 ± 2.85	1.00
Blood flow volume (mL/min)	4.57 ± 2.22	5.14 ± 2.03	0.62

Values are presented as mean±standard deviation

* $p < .05$, significant difference between the before and after exercise

Table 3. Comparison of parameters change before and after exercise in the control group

Parameters	Control Group (n=7)		P value
	Before exercise	After exercise	
Grip strength (kg)	24.05 ± 5.39	24.44 ± 5.24	0.070
Forearm circumference (cm)	21.21 ± 1.72	21.38 ± 1.64	0.061
Cephalic vein diameter (mm)	4.93 ± .64	5.23 ± 0.37	0.180
Blood flow velocity (cm/s)	93 ± 14.19	99.86 ± 21.48	0.105
Blood flow volume (mL/min)	495.43 ± 66.26	506.43 ± 80.95	0.144

Values are presented as mean±standard deviation

* $p < .05$, significant difference between the before and after exercise

Table 4. Comparison of gain score between intervention group and control group

Parameters	Gain Score		P value	Cohen D (d)
	Intervention group	Control group		
Grip strength	5.44 ± 0.58	0.38 ± 0.46	<0.001*	0.94
Forearm circumference	0.97 ± 0.39	0.17 ± 0.19	<0.001*	0.40
Cephalic vein diameter	0.61 ± 0.53	0.13 ± 0.18	0.046*	0.84
Blood flow velocity	8 ± 9.52	6.86 ± 9.53	0.334	-
Blood flow volume	21 ± 20.11	11 ± 17.33	0.035*	0.53

Values are presented as mean±standard deviation

* $p < .05$, significant difference between the before and after exercise

Small effect ($0 < d < .2$), moderate effect ($.2 < d < .8$), large effect ($d > .8$)

Comparison of Gain Score between two groups showed significant differences in grip strength, forearm circumference, cephalic vein diameter, and blood flow volume parameter ($p < .05$). However, the blood flow velocity

parameter did not show significant differences between the intervention group and control group ($p = .334$)(Table 4).

The Effect Size was analyzed for all parameters except blood flow velocity

parameter due to non-statistical significance level for this parameter. The grip strength parameter showed $ES=.94$, indicated that the exercise intervention had a large effect to increase grip strength ($d>.8$). The forearm circumference parameter showed $ES=.40$, indicated that the exercise intervention had a moderate effect to increase forearm circumference. The cephalic vein diameter parameter showed $ES=.84$, indicated that the exercise intervention had a large effect to improve diameter of cephalic vein ($d>.8$). And, the blood flow volume parameter showed $ES=0.53$, indicated that exercise intervention had a moderate effect to improve blood flow volume (Table 4).

Discussion

Hand exercise effect in muscle performance grip strength & forearm circumference

In this present study, 7 CKD patient who underwent AVF procedure and on routine haemodialysis were allocated in intervention group to receive 5-week hand exercise with hand gripper program. The result showed the grip strength parameter value increased significantly after 5-week hand exercise program. On the other hand, there were no significant difference for grip strength parameter in control group. The result also showed that 5-week hand exercise program had a large effect to increased grip strength.

Muscle adaptation during resistance exercise has been explained clearly by Kouidi and colleagues (1998). The resistance training can increase mean muscle cross sectional area about 29%, type-1 fiber area increase about 26% as well as increment of type-2 fiber area about 24%, and increase proportion of normal ratio between type-1 and type-2 muscle fiber in haemodialysis CKD patient. The condition above mentioned could promote improvement of muscle strength and function performance by enhancement of muscle oxidative, metabolic, and energetic mechanism.⁹ In accordance with the results, Naomi and

colleagues (2005) in a study of end stage kidney disease patients which were prescribed 50 repetitive handgrip contraction training at a strength of 60% of the maximum value and gradually increased up to 150 contraction showed that after 6 weeks of exercise program, handgrip strength was improved to 125% of the value before training.¹⁰

The forearm circumference was significantly increased after 5-week hand exercise program. It was a parameter for examining the general strength of the forearm muscles. We could presume that the significant increase in the forearm circumference resulted from the changes caused by the hand-squeezing exercise in the forearm muscle. It has been empirically proven by clinical trial that resistance training can increase muscle protein synthesis and muscle total volume.

These beneficial effect of hand exercise on muscle function in the present study is consistent with the findings after local or systemic physical training in previous studies.^{3-5,7,8,10,11}

Hand exercise effect in vascular response Cephalic vein diameter, blood flow volume and velocity

We have shown that in the intervention group, 5-week hand exercise program increases the diameter of cephalic vein and also increases blood flow volume significantly. The improvement of cephalic vein diameter is the result of increased blood flow in response to exercise. Our results support the previous findings that resistance hand exercise could significantly increase the vessel diameter and vasodilatation, also improve the blood flow volume considerably after the exercise program.³⁻⁵

Vascular response to exercise has been studied both in normal condition or in the presence of disease resulting new theories in terms of the mechanical, biochemical, and cellular vascular response mechanism to the

physical activity.⁶ Vascular acute response to physical activity was believed to be associated with muscle contraction process. The skeletal muscle flow increased in response to contractile activity. The increasing of blood flow through the vessel will increase shear stress which is the main stimulus in enlargement of vessel diameter. This condition leads to flow-mediated vasodilatation mechanism.^{11,12}

In this present study, as the cephalic vein diameter and blood flow volume improves, the blood flow velocity shows no significant increase.

Blood flow through the vascular circuit generally relates directly to the pressure gradient between the two ends of the vessel and inversely to the resistance encountered to blood flow, and the most important factor determining the resistance is vessel radius. Vascular resistance is inversely proportional to the vessel radius. Changes of vessel diameter can result in increases or decreases in vascular resistance. The smaller the vascular size, the greater resistance occurs, and vice versa. The cross-sectional area of vessel equals to the radius squared.^{11,12}

In the postoperative period, an AVF typically requires several months of maturation for the draining vein to dilate and for blood flow to increase. The fistula creates a pathway and acts as a short circuit between the high-pressure arterial system and the low-pressure venous system. Opening the fistula reduces peripheral resistance and dramatically increases flow. To accommodate this increased volume of blood flow through the fistula, without increasing the wall shear stress excessively, there must be a widening of the fistulous circuit. Corpataux et al. (2002) have shown that, as the venous limb of the BCF is subjected to high blood flow (20-fold increase), the cross-sectional area of the vein enlarges in response to the increased circumferential stress due to higher shear forces. Flow increases as a result

of both vasodilatation and vascular remodeling.¹³

Theoretically, the relationship between blood flow volume, velocity and vessel radius indicate that in a condition with constant vessel radius, changes in flow volume are proportionate to changes in velocity. On the other hand, vasodilatation by increasing the cross-sectional area of blood vessel tends to decrease the velocity.^{12,14} This theory supports our findings that there were increases in blood flow volume and cephalic vein diameter, whereas there was no difference in flow velocity. This illustrates the role of the endothelium, which reacts to an increased shear stress by producing vasodilator and growth factors whose remodelling effect leads to an increase in vessel cross-sectional area, accommodating the larger flow volume and hence reducing shear stress itself.^{6,11} However, there are several factors that contribute to the blood flow volume and velocity such as the flow of feeding artery side, blood viscosity, and vascular wall changes. Unfortunately, the current study did not include the arterial parameters measurement as the vascular response variable, and also could not rule out the possibility of blood viscosity influences as a confounding factor.

Kidney Disease Outcomes Quality Initiative (KDOQI) Vascular Access guidelines, suggest that a working AVF should have a blood flow >600 mL/min, a diameter >0.6 cm, and be at a depth of 0.6 cm (between 0.5 and 1.0 cm) from the surface, 6 weeks after its creation. In fistulas that are successfully maturing, flow increases rapidly post-surgery, from baseline values of 30–50 mL/min to 200–800 mL/min within 1 week, generally reaching flows >480 mL/min at 8 weeks.^{1,15} The results of current study shows that the 5-weeks hand exercise program has a large effect to increase the cephalic vein diameter (ES=.84) and moderate effect to increase the blood flow volume (ES=.53) compared to the control. Our results support the previous study findings by

those who exercised the AVF arm of 18 CKD patients for 4 weeks. Kong and colleagues (2014) found significant changes in cephalic vein size and blood flow volume after 4-weeks hand exercise program with hand gripper as well as with squeezing ball.⁴

Study limitation

The major limitations of our study were its small number of subjects and the short exercise period. In addition, compliance to the exercise program could not be directly supervised in the intervention group due to the home-based exercise study design. For these reasons, further studies with larger samples, longer period and direct supervision of exercise program are needed.

Conclusion

In summary, this study suggest that 5-weeks hand exercise program effectively increased the grip strength and forearm circumference, also can support the fistula maturation process by enhancing the vein size and flow volume.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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