Effect of home exercise rehabilitation on cardiopulmonary function in patients after PCI: a retrospective cohort study

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Abstract

Objectives

This study aimed to compare the effects of different durations of home exercise rehabilitation on left ventricular remodeling and cardiopulmonary function in patients with acute coronary syndrome (ACS) treated with percutaneous coronary intervention (PCI).

Methods

All patients received individualized home exercise rehabilitation guidance and treatment after discharge from the hospital. Echocardiography and CPET were performed before and after the rehabilitation intervention. The echocardiographic parameters and CPET results of the two groups were compared before and after rehabilitation. Differences between the groups were compared for each parameter.

Results

Forty patients were enrolled. Patients were divided into long-term home rehabilitation group (6–12 months, $n = 18$) and short-term home rehabilitation group (3 to < 6 months, $n = 22$).The CPET parameters $ATVO_2$, peak VO_2/kg, and peak METs in the long-term home rehabilitation group increased after rehabilitation compared with those before rehabilitation ($P < 0.05$). Except for the decrease in the VE/VCO_2 slope, which was not statistically significant ($P > 0.05$), $ATVO_2$, peak VO_2/HR, peak VO_2/kg, peak METs, and peak power all increased in the long-term home rehabilitation group compared with the short-term home rehabilitation group($P < 0.05$). LVEDd and LVESd were lower in the long-term home rehabilitation group than in the short-term home rehabilitation group($P < 0.05$). Multiple regression analysis of the correlation between LVEF and CPET parameters suggested that LVEF had a positive and statistically significant correlation with $ATVO_2$ and peak power (r = 0.7156828,$P = 0.009$ and r = 0.457907,$P = 0.034$).

Conclusion

Long-term home rehabilitation of patients with ACS after PCI improved the cardiopulmonary function and exercise capacity.

Introduction

The Summary of China Cardiovascular Health and Disease Report 2020 states that the prevalence of cardiovascular disease in China is continuously increasing, with a projected 330 million patients with cardiovascular disease at present, including 11.39 million with coronary heart disease. Moreover, the mortality rate of coronary heart disease continues to follow an upward trend since 2012[1]. Acute coronary syndrome (ACS) refers to a group of diseases caused by acute myocardial ischemia due to the rupture and thrombosis of unstable plaques in coronary arteries. ACS is often treated clinically by percutaneous coronary intervention (PCI) and drug therapy. A growing body of medical evidence suggests that exercise-focused cardiac rehabilitation is effective in preventing cardiac remodeling, reducing ischemia-related symptoms [2], and decreasing rehospitalization and mortality [3, 4]. Surgical and pharmacological treatments do not provide lasting improvement in the prognosis of patients with ACS, and controlling risk factors in patients with ACS through comprehensive cardiac rehabilitation therapy can restore patients to optimal physical, psychological, and social functioning. The American Heart Association (AHA), the American College of Cardiology Foundation（ACCF), the European Society of Cardiology (ESC), and the European Association for Cardiovascular Prevention and Rehabilitation（EACPR) have now introduced guidelines for cardiovascular disease prevention and rehabilitation that include exercise rehabilitation therapy, using an evidence-based medical approach to evaluation [5-7].

Although the benefits of cardiac rehabilitation are well known to the general public, only a minority of patients with cardiovascular disease participate in it [8]. At present, out-of-hospital exercise rehabilitation modalities include both outpatient rehabilitation and home rehabilitation, and many patients are unable to undergo exercise rehabilitation in an outpatient setting due to medical, economic, and social factors such as age, education, disease status, health insurance, work, and family [9, 10]. Therefore, studying the effect of home exercise rehabilitation on cardiopulmonary function in patients with cardiovascular disease was the main objective of this study. Also, the present study compared the differences in the effects of different exercise rehabilitation times on cardiopulmonary function and cardiac remodeling in patients after PCI to explore effective models that were more conducive to patients' cardiac rehabilitation.

Echocardiography and cardiopulmonary exercise testing (CPET) are currently the main methods to evaluate static and exercise cardiac function[11]. In this study, echocardiography and CPET were used to assess the differences in cardiopulmonary function in patients with ACS before and after exercise rehabilitation after PCI treatment.

Materials And Methods

1. Data source

Patients with ACS who underwent PCI at the Department of Cardiology,, from July 2018 to March 2021 were consecutively enrolled in the Electronic case database of the Affiliated Hospital of Qingdao University, using a retrospective analysis method. The inclusion criteria were as follows: (1) patients who were admitted to the hospital in the emergency or outpatient department, and were diagnosed with ACS and undergoing emergency or elective PCI; (2) patients who attended the cardiac rehabilitation center for recovery from cardiac rehabilitation intervention within 30 days after discharge; (3) patients echocardiography and CPET were assessed within 1 week before exercise rehabilitation and 3–12 months after exercise rehabilitation; and (4) patients who performed exercise at home as the rehabilitation mode under the guidance of the cardiac rehabilitation center and did not participate in outpatient home rehabilitation. The exclusion criteria were as follows[12]: (1) patients with unstable angina; (2) patients with systolic blood pressure >200 mmHg or diastolic blood pressure >110 mmHg when quiet and blood pressure dropped by >20 mmHg after sitting upright with symptoms; (3) patients with contraindications to exercise rehabilitation, including severe aortic stenosis, acute systemic disease or fever, uncontrolled atrial or ventricular arrhythmias, uncontrolled sinus tachycardia (>120 beats/min), uncontrolled heart failure, third-degree atrioventricular block without a pacemaker, and active pericarditis or myocarditis; (4) patients with less than 3 months of exercise rehabilitation; and (5) patients with other severe systemic abnormalities that could limit the exercise capacity. A total of 40 patients were included according to the aforementioned riteria. The study protocol conformed to the Declaration of Helsinki, and its subsequent amendments and was approved by the local ethics committee of Affiliated Hospital of Qingdao University.

2. Study methods

2.1 Diagnostic criteria

All patients were clinically diagnosed with ACS according to the ESC guidelines[13].

2.2 Grouping criteria

Patients with ACS after PCI were divided into long-term home rehabilitation group (6–12 months, n = 18) and short-term home rehabilitation group (3–<6 months, n = 22) according to the length of their home exercise rehabilitation. Basic characteristics of the patients, such as age, sex, body mass index (BMI), abdominal circumference, classification of ACS, risk factors, past history, smoking status; echocardiographic findings; and coronary artery stent implantation status, were collected through an electronic case system. All patients were excluded from contraindications to exercise and given standardized home exercise rehabilitation, two to three times/week, and monthly cardiac rehabilitation clinic follow-up visits, which included exercise instruction, blood biochemical parameters, echocardiogram, and medication adjustment. Patients with complete follow-up data were included in this retrospective study.

2.3 Screening process

According to the aforementioned criteria, among 460 patients with post-PCI ACS participating in cardiac rehabilitation interventions in the Cardiac Rehabilitation Center database, 388 patients were lost to follow-up and 72 were followed up. Excluding 7 patients who were undergoing outpatient rehabilitation and 25 patients who had been in home exercise rehabilitation for less than 3 months, the number of repeat patients who met the inclusion criteria was 40. The number of patients who finally completed home exercise rehabilitation for 3 to <6 months was 22, and the number of patients who finally completed home exercise rehabilitation for 6–12 months was 18 (Fig. 1).

2.4 Cardiorespiratory exercise loading test

Cardiorespiratory exercise loading tests were performed using the Omnia software system from COSMED, Inc (Italy). A power bicycle was used to complete the symptom-limited exercise test according to the continuous incremental power protocol (RAMP protocol) [14]. The procedure was to first rest for 3 min and then warm up for 1 min at a pedaling rate of 60–65 rpm without load. Incremental power per minute was calculated with $V0_2max$ (mL/min) = [height (cm)-age (year)] × 20 for men and $V0_2max$ (mL/min) = [height (cm)-age (year)] × 14 for women. Incremental power per minute = ($V0_2max$ - resting VO_2)/100. Patients were given as much time as possible to reach the maximum exercise power within 8-12 min, with a recovery period of 6 min. The indications for the termination of the test were based on the AHA scientific statement on exercise testing and training standards [15]. The criteria for the development of the exercise rehabilitation protocol were based on the AACVPR guidelines[14 15, 16].

2.5 Statistical methods

Statistical analysis of the data was performed using Stata 15.0. A paired-samples *t* test was used to analyze the differences between groups, and the differences were considered statistically significant if the *P* value was less than 0.05. The effect of left ventricular ejection fraction (LVEF) on CPET indexes was also analyzed using scatter plots and multiple regression.

Results

3.1 Comparison of the results of clinical baseline characteristics of patients with ACS

When comparing the general information and risk factors of the two groups of patients before exercise, no statistically significant differences were found in the baseline information (all *P* values > 0.05), except for a statistically significant difference in the mean number of patients with three stents implanted in both groups (*P* = 0.0308) (Table 1).

Table 1. Comparison of clinical baseline characteristics of patients with ACS

Item	Long-term home rehabilitation group (mean value)	Short-term home rehabilitation group (mean value)	Mean difference	*P* value
Men/Women	0.7777778	0.9545455	-0.1767677	0.0972
Age (year)	51.66667	49.09091	2.575758	0.4690
BMI (kg/m^2)	23.90278	25.59727	-1.694495	0.1528
Number of stents				
1	0.5	0.2272727	0.2727273	0.0752
2	0.2222222	0.2727273	-0.0505051	0.7221
3	0	0.2272727	-0.2272727	0.0308
4	0.0555556	0.0909091	-0.0353535	0.6823
STEMI				
Anterior myocardial infarction	0.2777	0.2272	0.0505	0.7221
Anteroseptal myocardial infarction	0.0556	0.0909	-0.0353	0.6823
Inferior myocardial infarction	0.2777	0.0909	0.1868	0.1281
Lateral myocardial infarction	0.0556	0.0909	-0.0353	0.6823
Right ventricle myocardial infarction	0	0.0454	-0.0454	0.3725
NSTEACS	0.3888	0.5	-0.1112	0.4949
Complications				
Hypertension	0.7777	0.5454	0.2323	0.1319
Diabetes	0.2222	0.2272	-0.005	0.9706
Hyperlipidemia	0.5555	0.5	0.0555	0.7345
Hyperuricemia	0.1111	0.1363	-0.0252	0.8160
Smoking (year × number/day)	98.33333	153.1818	-54.84848	0.4222

3.2 Comparison of CPET

3.2.1 Comparison of CPET parameters before and after rehabilitation in the long-term home rehabilitation group

Table 2 shows the comparison of CPET parameters before and after rehabilitation in the long-term home rehabilitation group. The results of the *t* test showed that anaerobic threshold (AT VO_2), peak oxygen pulse (VO_2/HR), peak kilogram oxygen uptake (peak VO_2/kg), and peak metabolic equivalents (peak METs) increased in the long-term home rehabilitation group after rehabilitation compared with that before rehabilitation , while the VE/VCO_2 slope decreased. The differences in AT VO_2, peak VO_2/kg, and peak METs were statistically significant ($P < 0.05$) in terms of the significance shown by the *P* values.

Table 2. Comparison of CPET parameters before and after rehabilitation in the long-term home rehabilitation group

Item	Mean value before rehabilitation	Mean value after rehabilitation	Mean difference	*P* value
ATVO_2	1015.105	1276.522	261.4173	0.0282
Peak VO_2/HR	10.82778	12.78333	1.955556	0.2736
VE/VCO_2 slpoe	30.34444	28.24444	-2.1	0.4039
Peak VO_2/kg	17.11	21.73389	4.623889	0.0230
Peak METs	4.833333	6.4	1.566667	0.0044
Peak Power	100.3889	120.4444	20.05556	0.0706

3.2.2 Comparison of CPET parameters before and after rehabilitation in the short-term home rehabilitation group

Table 3 shows the comparison of CPET parameters before and after rehabilitation in the short-term home rehabilitation group. The results of the *t* test showed that AT VO_2, peak METs, and peak power increased in the short-term home rehabilitation group after rehabilitation compared with that before rehabilitation , while the peak VO_2/HR, VE/VCO_2 slope, peak VO_2/kg decreased . In terms of the significance shown by the *P* value, none of the aforementioned indicators differed statistically significantly ($P > 0.05$).

Table 3. Comparison of CPET parameters before and after rehabilitation in the short-term home rehabilitation group

Item	Mean value before rehabilitation	Mean value after rehabilitation	Mean difference	*P* value
$ATVO_2$	1054.372	1116.902	62.52966	0.4544
Peak VO_2/HR	10.98682	10.61364	-0.3731818	0.6973
VE/VCO_2 slpoe	28.61864	28.12727	-0.4913636	0.7225
Peak VO_2/kg	18.06773	17.88227	-0.1854545	0.8747
Peak METs	5.168182	5.231818	0.0636364	0.8697
Peak Power	100.5	104.9091	4.409091	0.6043

3.2.3 Comparison of the changes in CPET parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups

Table 4 shows the comparison of the changes in CPET parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups. The results of the *t* test showed that the changes in each CPET in the long-term home rehabilitation group was statistically superior compared with the short-term home rehabilitation group, except for VE/VCO_2 slope, which was not statistically significant, and the changes in other indicators in the long-term home rehabilitation group were better than those in the short-term home rehabilitation group and were statistically significant ($P < 0.05$).

Table 4. Comparison of changes in CPET parameters before and after rehabilitation in the long-term and short-term home rehabilitation groups

Item	Long-term home rehabilitation group (mean value)	Short-term home rehabilitation group (mean value)	Mean difference	*P* value
△AT VO_2	261.4173	62.52966	198.8876	0.0160
△peak VO_2/HR	1.955556	-0.3731818	2.328737	0.0036
△VE/VCO_2 slope	-2.1	-0.4913636	-1.608636	0.3438
△peak VO_2/kg	4.623889	-0.1854545	4.809343	0.0042
△peak METs	1.566667	0.0636364	1.50303	0.0021
△peak Power	20.05556	4.409091	15.64646	0.0254

3.3 Comparison of echocardiographic results

3.3.1 Comparison of echocardiographic parameters before and after rehabilitation in the long-term home rehabilitation group

Table 5 shows the comparison of echocardiographic parameters before and after rehabilitation in the long-term home rehabilitation group. No statistically significant difference was found between the echocardiographic parameters before and after rehabilitation ($P > 0.05$).

Table 5. Comparison of echocardiographic parameters before and after rehabilitation in the long-term home rehabilitation group

Item	Mean value before rehabilitation	Mean value after rehabilitation	Mean difference	*P* value
LVEDd (mm)	47.38889	48.38889	-1	0.4866
LVESd (mm)	30.72222	31.88889	-1.166667	0.4149
IVST (mm)	9.277778	9.222222	0.0555556	0.8853
LVPW (mm)	9.166667	9	0.1666667	0.5239
LVMI (g/m^2)	85.00127	86.48602	-1.484748	0.7136
LVEF (%)	0.5994444	0.62	-0.0205556	0.4012

3.3.2 Comparison of echocardiographic parameters before and after rehabilitation in the short-term home rehabilitation group

Table 6 shows the comparison of echocardiographic parameters before and after rehabilitation in the short-term home rehabilitation group. No statistically significant difference was observed between the echocardiographic parameters before and after rehabilitation ($P > 0.05$).

Table 6. Comparison of echocardiographic parameters before and after rehabilitation in the short-term home rehabilitation group

Item	Mean value before rehabilitation	Mean value after rehabilitation	Mean difference	*P* value
LVEDd (mm)	48.72727	47.40909	-1.318182	0.4955
LVESd (mm)	31.59091	30.81818	-0.7727273	0.6757
IVST (mm)	10.31818	10.13636	-0.1818182	0.7026
LVPWT (mm)	9.409091	9.5	0.0909091	0.7718
LVMI (g/m^2)	90.75854	86.88073	-3.877813	0.5784
LVEF (%)	0.6113636	0.6186364	0.0072727	0.7419

3.3.3 Comparison of mean values of changes in echocardiographic parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups

Table 7 shows the comparison of mean values of changes in echocardiographic parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups. In terms of the significance of *P* values, the changes in the left ventricular end-diastolic internal diameter (△LVEDd) and left ventricular end-systolic internal diameter (△LVESd) were statistically significant in the long-term home rehabilitation group compared with the short-term home rehabilitation group, and the difference was statistically significant ($P < 0.05$). The changes in left ventricular mass index (△LVMI) and The changes in left ventricular ejection fraction(△LVEF) were slightly elevated in the long-term rehabilitation group compared with the short-term rehabilitation group, and the difference was not statistically significant ($P > 0.05$).

Table 7. Comparison of changes in echocardiographic parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups

Item	Long-term home rehabilitation group (mean value)	Short-term home rehabilitation group (mean value)	Mean difference	*P* value
△LVEDd (mm)	1	-1.318182	2.318182	0.0031
△LVESd (mm)	1.166667	-0.7727273	1.939394	0.0306
△IVST (mm)	-0.0555556	-0.1818182	0.1262626	0.7500
△LVPWT (mm)	-0.1666667	0.0909091	-0.2575758	0.4855
△LVMI (g/m^2)	1.484748	-3.877813	5.362561	0.1764
△LVEF(%)	0.0205556	0.0072727	0.0132828	0.3998

3.3.4 Correlation analysis of LVEF and CPET indexes

The scatter plots shown in Figures 2–7 illustrate that LVEF correlated positively with $ATVO_2$, peak VO_2/HR, peak VO_2/kg, peak METs, and peak power, and negatively with VE/VCO_2 slope.

3.3.5 Multiple regression method analysis of the correlation between LVEF and CPET parameters

As shown in Table 8, LVEF showed a positive and statistically significant correlation with AT VO_2 and peak power (r=0.7156828,P=0.009 and r=0.457907,P=0.034); positive but not statistically significant correlation with peakVO_2/HR, peak VO_2/kg, and peak METs (r=0.3845365,P=0.170, r=0.4081052,P=0.144, r=0.4963648, P=0.079); and negative and statistically significant correlation with VE/VCO_2 slope (r=-0.4973823,P=0.003).

Table 8. Analysis of the effect of LVEF on CPET indicators

LVEF	AT VO_2	peakVO_2/HR	VE/VCO_2 slope	peak VO_2/kg	peak METs	peak power
r value	0.7156828	0.3845365	-0.4973823	0.4081052	0.4963648	0.457907
P value	0.009	0.170	0.003	0.144	0.079	0.034

Discussion

Data from the GRACE Acute Coronary Events Registry study indicated that the rate of mortality, stroke, and rehospitalization in patients with coronary artery disease was as high as 25% within 6 months of discharge. The 4-year cumulative morbidity and mortality rates were as high as 22.6%. PCI is an important hemodynamic reconstructive tool to improve myocardial blood perfusion in patients with coronary artery disease. However, surgery and drug therapy alone do not consistently improve patient prognosis. Most patients suffer from decreased exercise tolerance and psychosomatic disorders, such as anxiety and depression, after surgery[17]. In the last 20 years, a large number of studies showed that cardiac rehabilitation had significant benefits in improving the prognosis of patients with coronary artery disease, improving cardiopulmonary function, reducing psychological disorders, and reducing health-care costs. The current post-PCI rehabilitation program for coronary artery disease was divided into phase I rehabilitation (early inpatient rehabilitation), phase II rehabilitation (early post-PCI outpatient rehabilitation), and phase III rehabilitation (long-term out-of-hospital rehabilitation) [18]. At present, the participation rate of cardiac rehabilitation in China is significantly insufficient, and various factors, such as family, economic, and social factors, limit patients' participation in outpatient phase II rehabilitation. Therefore, increasing the participation in home rehabilitation may be a possible effective strategy to address the bottleneck of cardiac rehabilitation treatment. A meta-analysis showed that home and outpatient rehabilitation models for low-risk patients after PCI had similar benefits in terms of mortality, cardiovascular events, exercise capacity, and correction of cardiovascular risk factors, and compliance was significantly better in the home rehabilitation model than in the outpatient rehabilitation model [19]. Few retrospective studies have reported on home exercise rehabilitation in patients with ACS after PCI; however, further research is needed on the effect of a single home exercise rehabilitation mode on cardiopulmonary function in patients after PCI.

The present study retrospectively analyzed patients who attended our cardiac rehabilitation center for recovery from cardiac rehabilitation intervention within 30 days after discharge from the hospital, with home exercise as the mode of rehabilitation. The effects of different rehabilitation durations on patients' echocardiographic parameters, cardiopulmonary function, and exercise capacity were analyzed. The statistical results had some limitations because only a few patients met the inclusion criteria. Hence, further studies with expanded sample size are needed. The statistical results of this study suggested that the long-term home rehabilitation group had different degrees of increase in AT VO_2, peak VO_2/HR, peak METs, peak VO_2/kg, and peak power after rehabilitation than before rehabilitation, among which the differences in ATVO_2, peak VO_2/kg, and peak METs were statistically significant ($P < 0.05$). The VE/VCO_2 slope was slightly reduced before rehabilitation compared with after rehabilitation, indicating that long-term home rehabilitation could improve exercise cardiopulmonary function and increase the respiratory efficiency of patients. In the short-term home rehabilitation group, the aforementioned indexes also showed the same change pattern, but the difference was not statistically significant. The long-term home rehabilitation group was statistically superior to the short-term home rehabilitation group, except for the VE/VCO_2 slope, which was not statistically significant; the changes in other indicators in the long-term home rehabilitation group were statistically significant ($P < 0.05$), suggesting that the longer the patients adhered to regular home exercise rehabilitation, the more significant the improvement and benefit in cardiopulmonary function. Comparison of the changes in echocardiographic parameters before and after rehabilitation between the long-term and short-term home rehabilitation groups showed no statistically significant difference, except for the differences in LVEDd and LVESd ($P < 0.05$), suggesting that exercise rehabilitation might delay ventricular remodeling and prevent the occurrence of left ventricular insufficiency in patients. Although no statistically significant difference was found in the changes in LVEF between the two groups, a mild increase was found in the LVEF. The results of the correlation between LVEF and CPET parameters analyzed by the multiple regression method suggested that the improvement in patients' cardiopulmonary function might be related to the improvement in patients' cardiac ejection function. In conclusion, encouraging patients with ACS to develop an individualized exercise program based on the results of the exercise cardiopulmonary test after PCI, adopting a home rehabilitation model, and adhering to long-term exercise rehabilitation can improve patients' cardiopulmonary function and exercise capacity and prevent the occurrence of cardiac insufficiency.

Conclusion

The statistical results of this study suggested that the longer the patients adhered to regular home exercise rehabilitation, the more significant the improvement and benefit in cardiopulmonary function.

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the local ethics committee of Affiliated Hospital of Qingdao University(DNR:QYFYwzll26559). Informed consent was obtained from all subjects involved in the study.

Consent for publication

Not applicable.

Availability of data and materials

For information regarding data availability, please contact the corresponding author. The data are not publicly available due to privacy restrictions and protection of personal data.

Competing interests

The authors declare that they have no competing interests.

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Author Contributions

Jidong Zhang conducted the statistical analyses and writed the manuscript. Fuhai Li,Yan Li,Lihua Cao,Chunli Cui participated in the study design and assisted in the writing of the manuscript. Wenzhong Zhang conducted the statistical analyses.Zhexun Lian provided expert guidance in the design and conduct of this study and assisted in the writing of the manuscript.

Each author made substantial contributions to the conception or design of the work, the acquisition, analysis or interpretation of data, and drafting and final approval of the manuscript.

All authors read and approved the final manuscript. Zhexun Lian conceived the study and had ultimate oversight for the design and conduct and writing of this manuscript.

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Figures

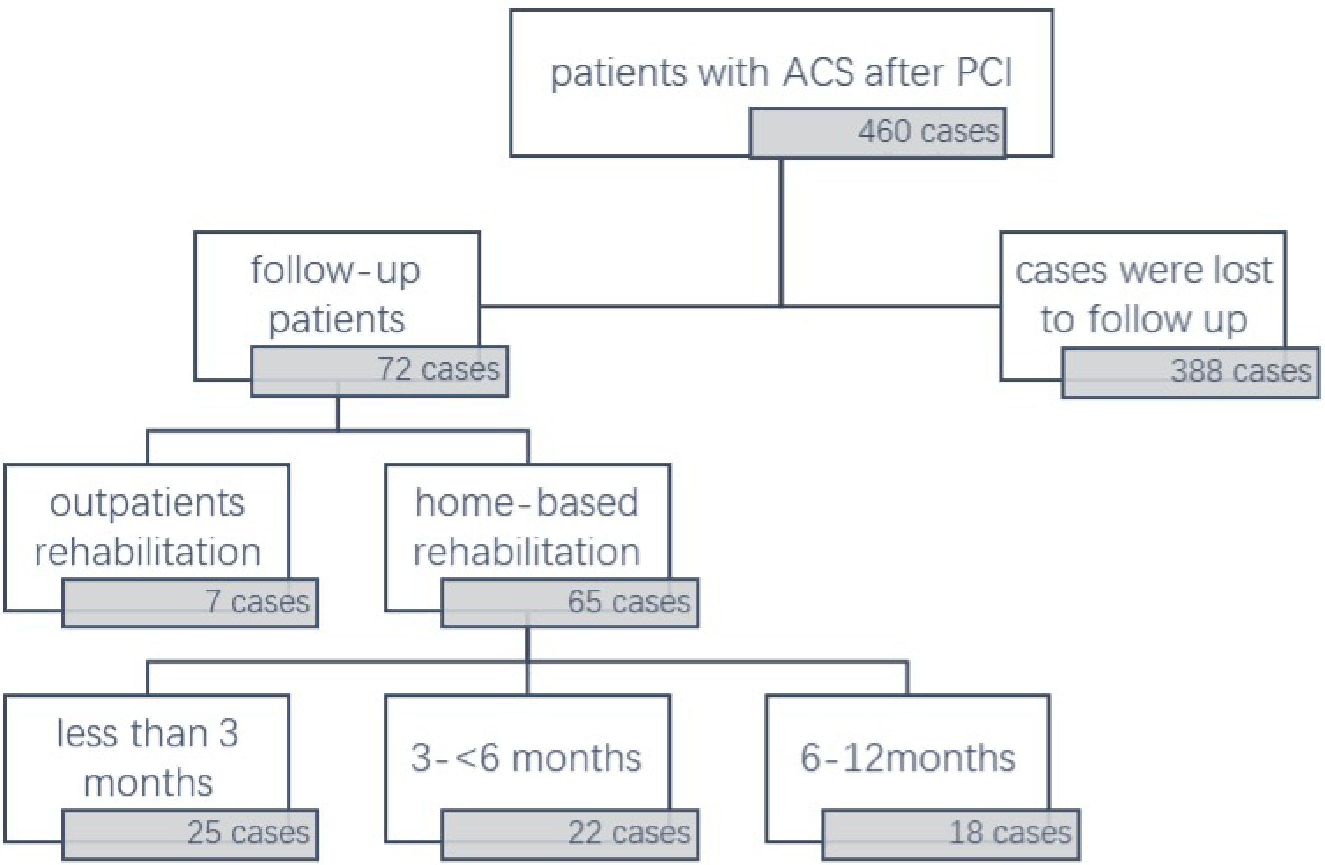

Figure 1

Patient screening process

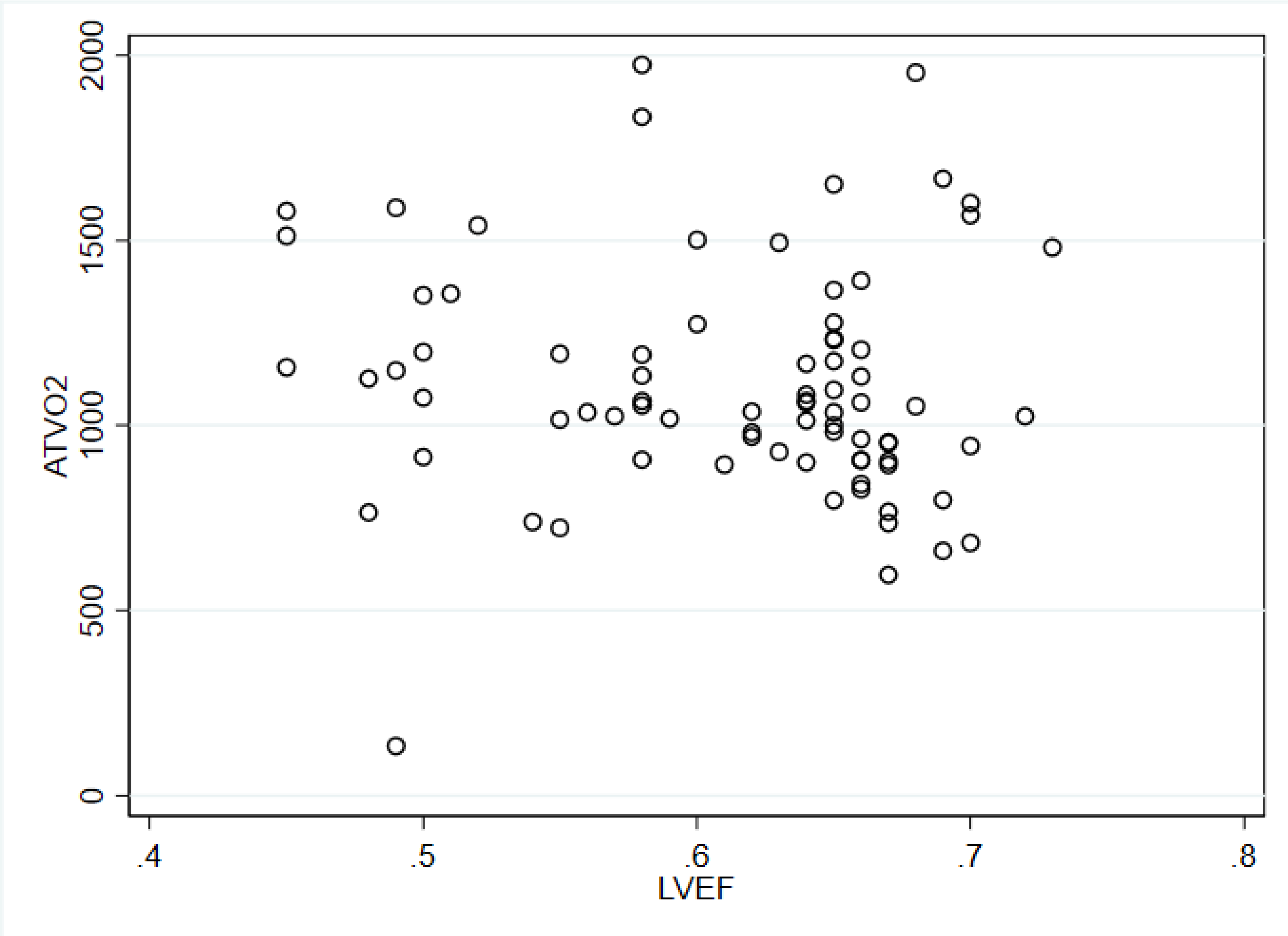

Figure 2

Scatterplot of correlation between LVEF and AT VO_2.

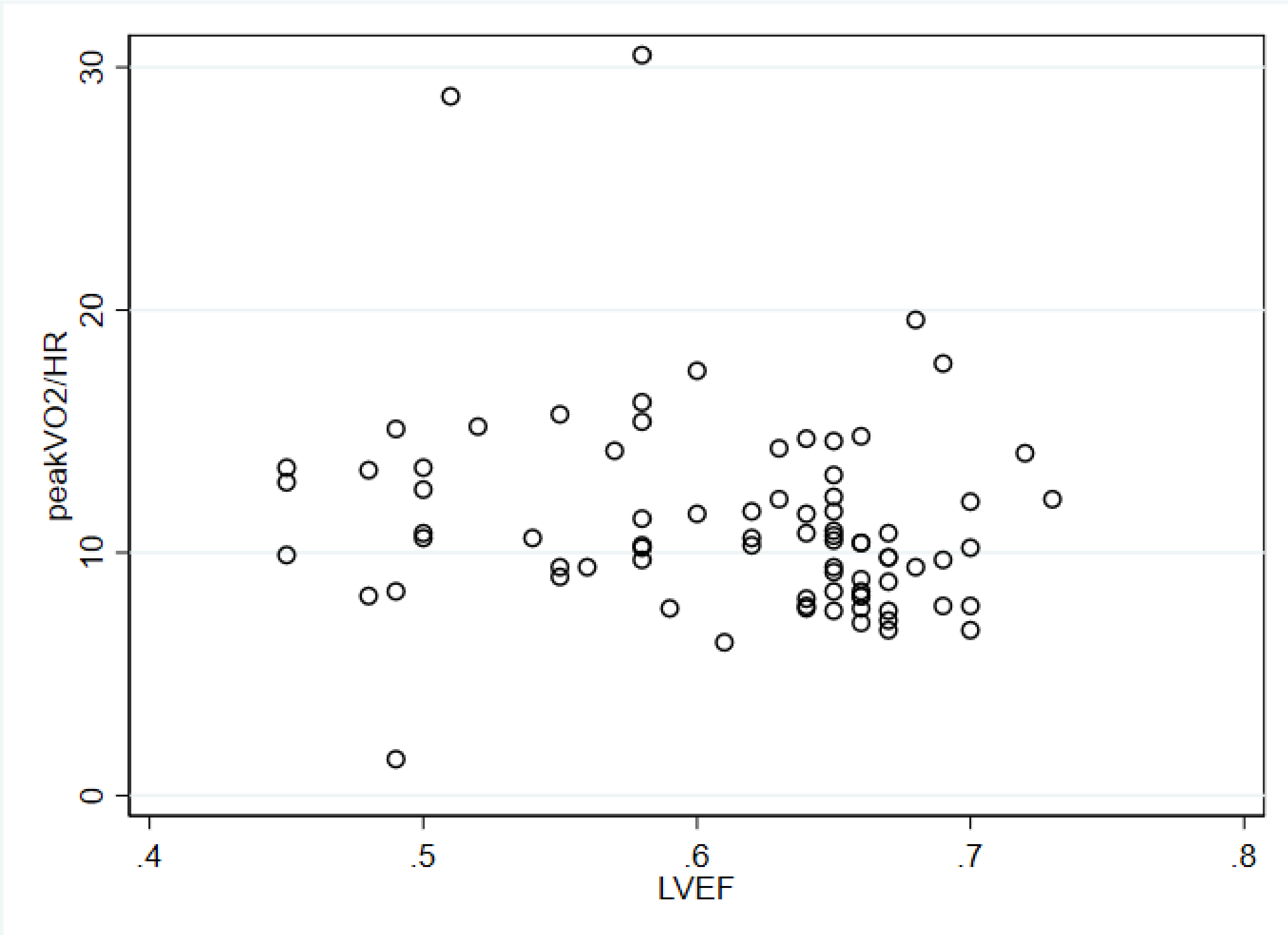

Figure 3

Scatterplot of correlation between LVEF and peak VO_2/HR.

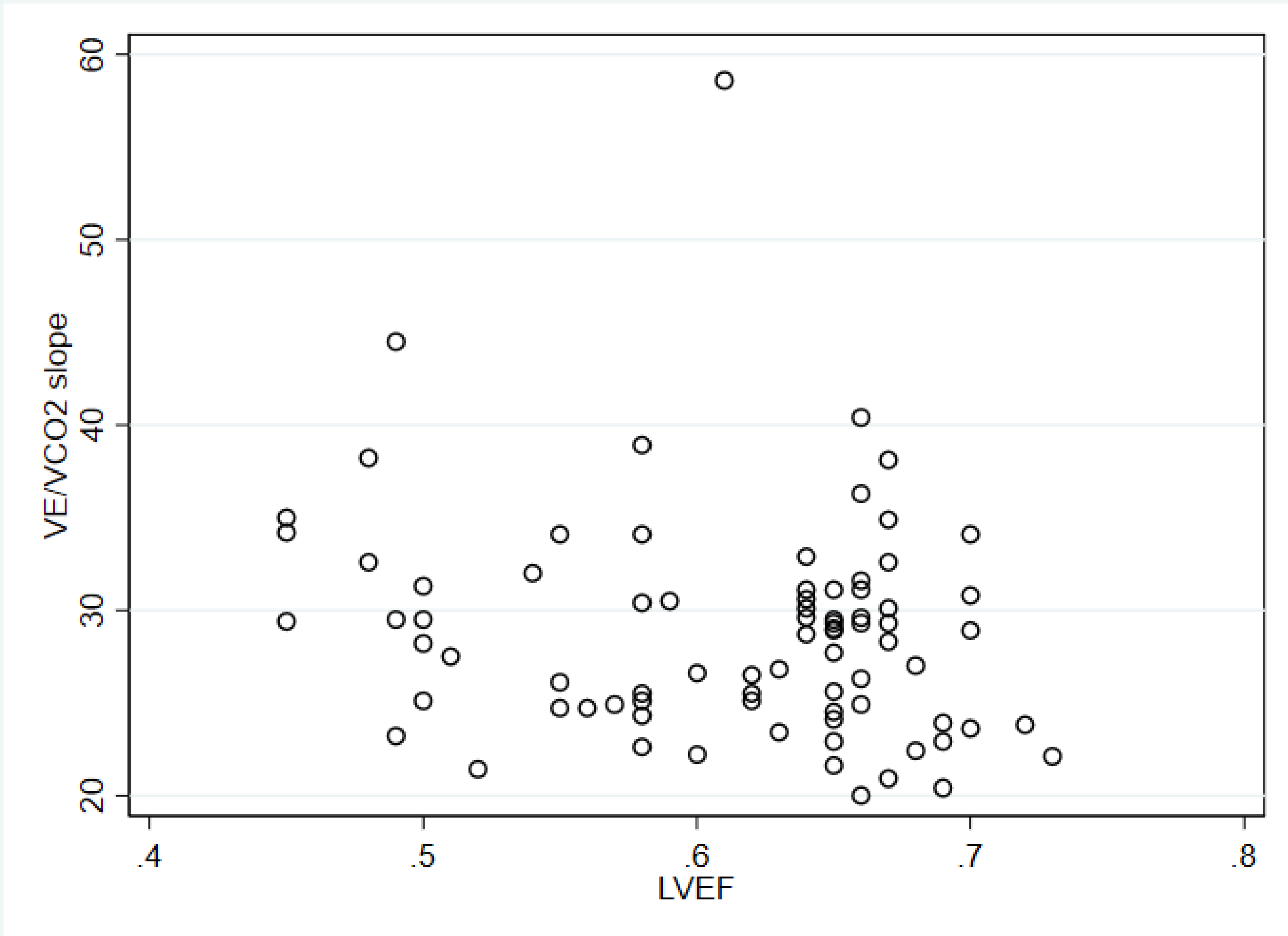

Figure 4

Scatterplot of correlation between LVEF and VE/VCO_2 slope.

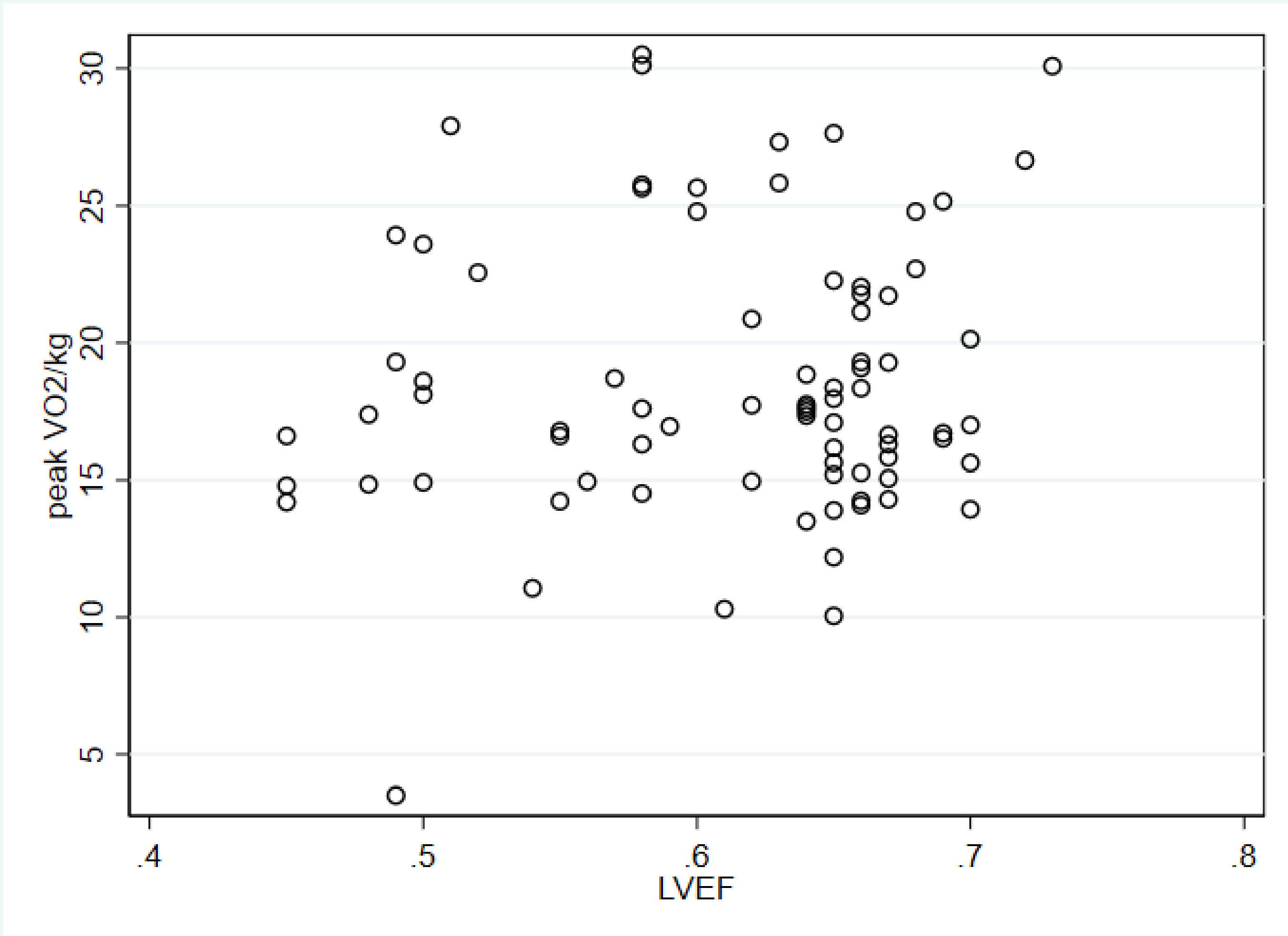

Figure 5

Scatterplot of correlation between LVEF and peak VO_2/kg.

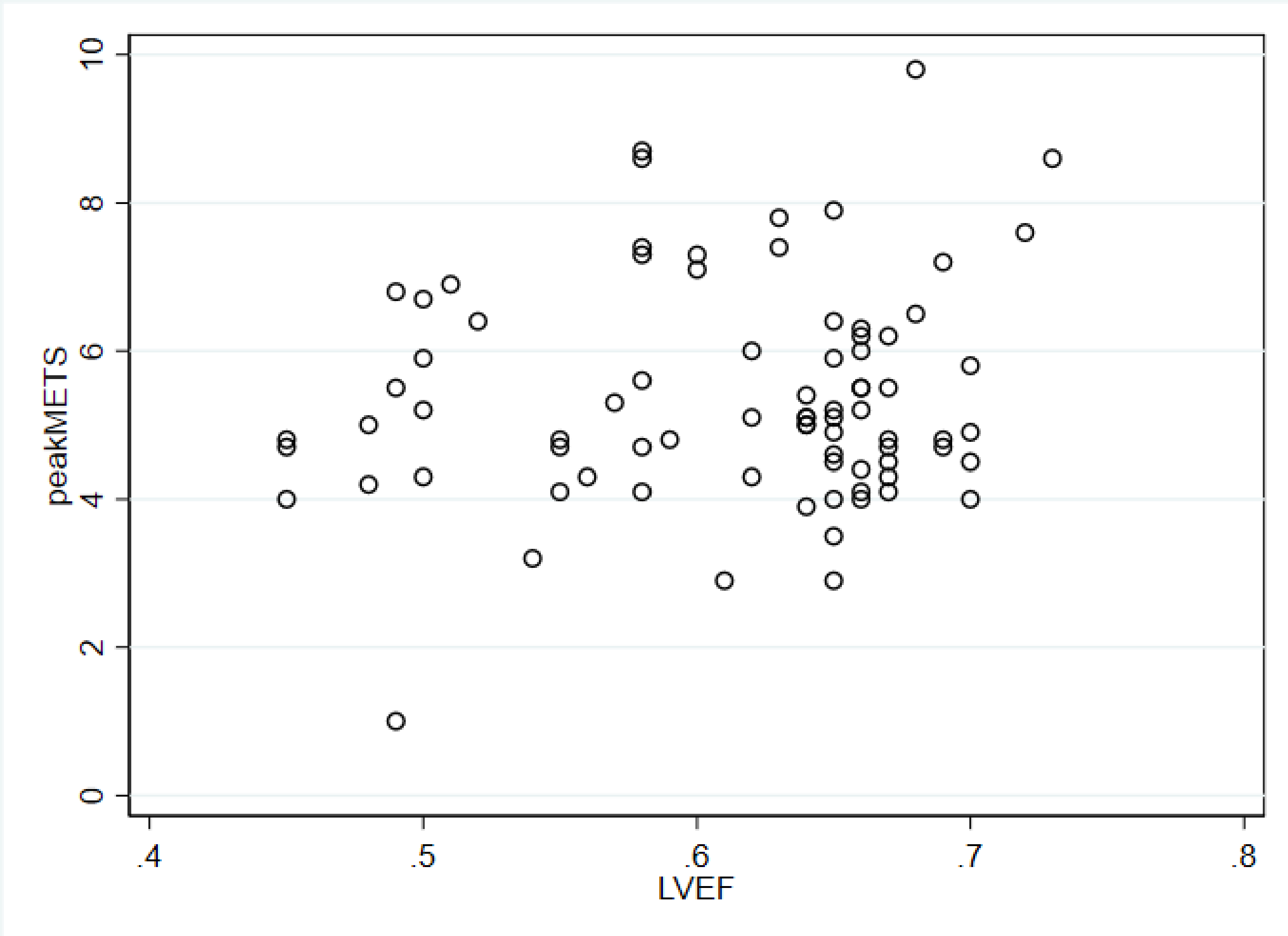

Figure 6

Scatterplot of correlation between LVEF and peak METs.

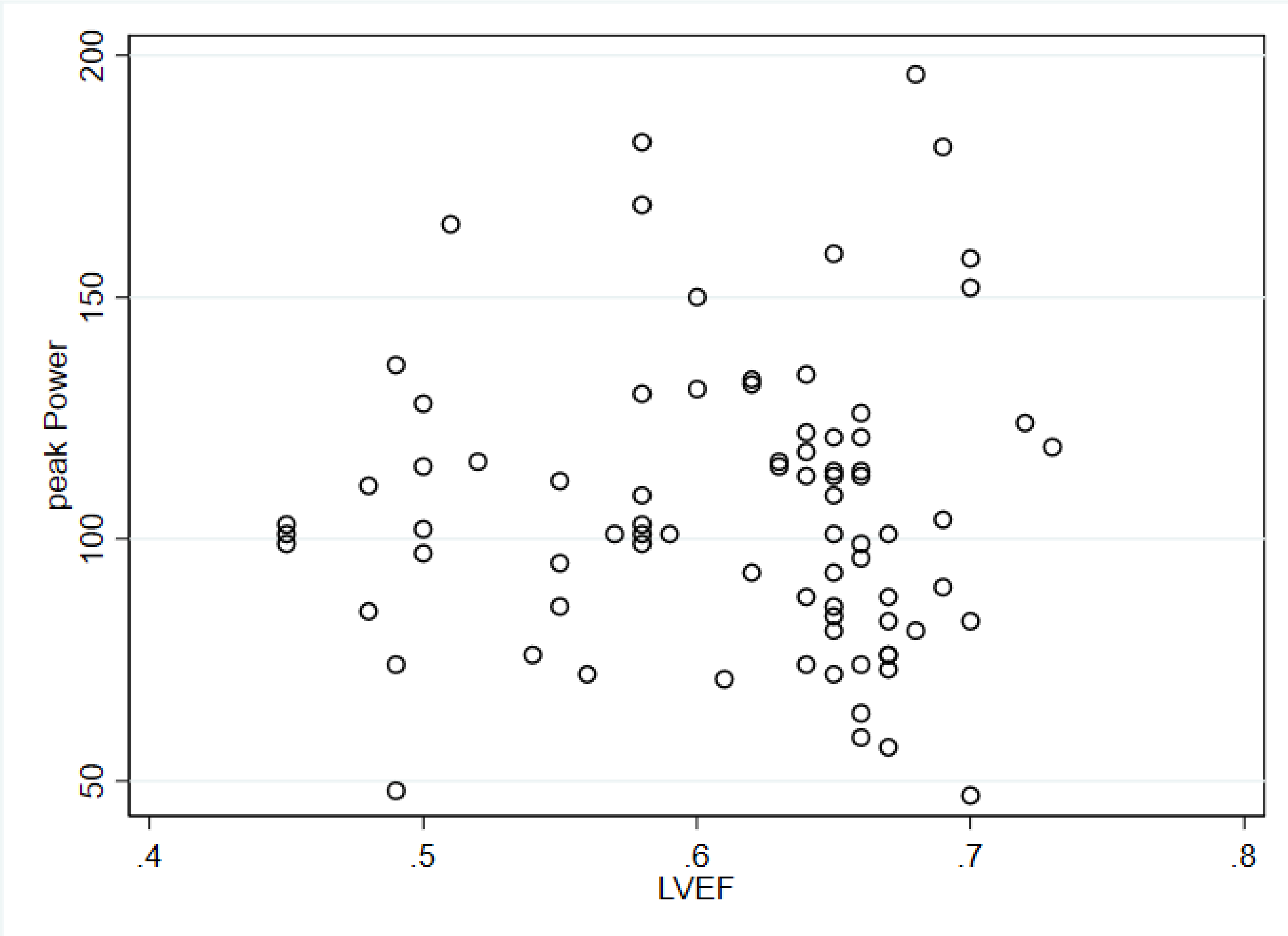

Figure 7

Scatterplot of correlation between LVEF and peak power.