Original Article

Retrospective analysis of exercise capacity in patients with coronary artery disease after percutaneous coronary intervention or coronary artery bypass graft

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ABSTRACT

Objectives: To describe the current state of exercise capacity as well as to identify its predictors in patients with coronary artery disease (CAD) following percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG) in the mainland of China.

Methods: A retrospective study design was employed. We evaluated 230 CAD patients following PCI or CABG in a cardiac rehabilitation center from January 2019 to October 2019. The patients were referred to undergo incremental cardiopulmonary exercise testing with a cycle ergometer. The Zung Self-Rating Anxiety Scale and the Zung Self-Rating Depression Scale were used to evaluate patients’ mental health. Statistical analysis was performed using the chi-square test, Fisher’s exact test, t-test, Mann-Whitney U test, and binary logistic regression.

Results: Among the 230 patients, 223 patients demonstrated reduced exercise capacity. Results of the logistic regression analysis showed that anxiety (OR = 1.13, 95% CI 1.01–1.32, P = 0.029) was an independent risk factor for reduced exercise capacity in patients following the PCI or CABG.

Conclusions: Exercise capacity of Chinese CAD patients after PCI or CABG was relatively poor. Alleviating symptoms of anxiety and making exercise prescriptions according to the results of the cardiopulmonary exercise test should be considered during the intervention to improve CAD patients’ exercise capacity.

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What is known?

- Exercise capacity is highly related to morbidity and mortality in cardiovascular disease (CVD) populations. Previous studies have shown that the major factors influencing exercise capacity in coronary artery disease (CAD) patients include demographic and disease factors.

What is new?

- Decreased exercise capacity is common in CAD patients after percutaneous coronary intervention or coronary artery bypass graft in the mainland of China.

- This study highlights the importance to alleviate symptoms of anxiety and make exercise prescription according to patients’ cardiopulmonary exercise test results during the intervention to improve exercise capacity.

1. Introduction

Coronary artery disease (CAD), also described as coronary heart disease (CHD), is currently one of the most severe diseases with high global morbidity and mortality rates [1]. The WHO [2] has described CHD as the leading cause of death around the world, accounting for at least nine million deaths in 2019. Recently, a study estimated that CAD prevalence in China was 110 million, and the...
mortality rate continued to rise from 2002 to 2017, reaching 122.04 per 100,000 in rural areas and 115.32 per 100,000 in urban areas [3].

Percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) are common treatments for CAD [4]. In 2017, more than 45,000 cases of CABG were performed in the mainland of China and continued to increase at an annual rate of 10% [1]. The total mortality rate of CABG in a large-scale heart center was 1.9%, and the incidence of major complications was 6.4%. In addition, the total number of cases of PCI performed in 2018 was 915,256, which increased by 21.5% compared with 2017 [3]. The risk of death of CAD patients was still >30% a decade after the establishment of PCI, 32.3% of patients experienced angina pectoris each year, and the rate of stent restenosis was 1% [5,6]. Numerous postoperative patients with CAD develop postoperative complications. To reduce the rate of re-infarction and all-cause mortality and cardiovascular risk factor burden and improve the quality of life of CAD patients who have undergone PCI or CABG, cardiac rehabilitation (CR) has been utilized as the most efficacious evidenced-based treatment for cardiovascular disease (CVD) [7,8].

CR is a secondary prevention program primarily delivered in an outpatient setting. It is composed of structured exercise training, a healthy diet, risk factor management with education, and coping with stress [9,10]. Exercise training is one of the core components of cardiac rehabilitation that improves central hemodynamics and enhances the oxidative capacity of the muscles in addition to offering many other benefits such as reducing in peripheral resistance, decreasing cardiomegaly, and lowering resting plasma epinephrine levels [11,12]. CR has become a significant part of primary and secondary prevention of heart disease, as well as having perfect clinical practice guidelines in developed countries, especially in the United States, Europe, Japan, and other countries and regions [13]. However, the practice of CR in the mainland of China is at its initial stage [14].

Exercise capacity, which is assessed based on peak oxygen uptake (peak VO2), is considered the gold standard for assessing aerobic exercise intensity and is generally used in formulating a safe, effective, and individualized exercise prescription for CR and return to work and daily activity recommendations [15–17]. Peak VO2 is highly related to morbidity and mortality in CVD populations [18–20]. Furthermore, Peak VO2 was also expressed as metabolic equivalent (MET, 1 MET = 3.5 ml·kg⁻¹·min⁻¹·VO2). Kodama et al. [21] observed that participants with a maximal exercise capacity of 7.9 METs or more had substantially lower rates of all-cause mortality and CAD events compared with those with a maximal exercise capacity of less than 7.9 METs. The scientific statement of the American Heart Association (AHA) indicates that the strongest predictor for mortality is exercise capacity compared with other established risk factors, including smoking, hypertension, type 2 diabetes mellitus, and high cholesterol, and including exercise capacity as a traditional risk factor markedly improves risk reclassification for adverse outcomes. In addition, AHA emphasized that health professionals utilize exercise capacity as a therapeutic outcome [22].

Current studies on factors influencing the exercise capacity of CAD patients have mainly been conducted in western countries. The latest study that evaluated predictors of exercise capacity in 1,282 elderly cardiac patients pre-CR in Europe has demonstrated that CABG, decreased left ventricular ejection fraction, as well as nephropathy and peripheral arterial disease are associated with low peak VO2 [23]. Another large study conducted in the USA examined factors influencing exercise capacity in 2,869 patients undergoing cardiac rehabilitation, which include female sex, CABG, and hypertension [17]. In addition, in nearly 1,000 CAD patients from Belgium, age, male sex, BMI, New York Heart Association class, resting and peak heart rate, fasting blood glucose, and β-blockers were found to be predictors of exercise capacity [24]. There is, however, to the best of our knowledge, few studies [25,26] in the mainland of China that have reported factors related to exercise capacity in CAD patients. Niu et al. [25] illustrated that history of diabetes mellitus and history of type C lesions are the independent risk factors for reduced exercise capacity. Similarly, another study reported that diabetes mellitus and myocardial infarction are independently associated with reduced exercise capacity [26]. However, the sample size in these studies was small. To sum up, previous studies have shown that the major factors influencing exercise capacity in CAD patients include demographic and disease factors. Although other studies have demonstrated that psychological factors (i.e., anxiety or depression) are also associated with the exercise capacity of CAD patients, investigations on the impact of psychological factors in Chinese CAD patients are limited [27,28]. Moreover, anxiety and depression are common occurrences in patients with CAD [29–31]. Studies have demonstrated that anxiety and depression are both risk factors for CAD and play important roles in the development, rehabilitation and prognosis of CAD [30,32,33]. Thus, the importance of focusing on anxiety and depression in CAD patients has been emphasized [33]. In addition, the status of exercise capacity of Chinese CAD patients after CABG is not clear. The identification of predictors of exercise capacity may help improve future study designs by revealing confounding variables, as well as providing a theoretical basis for future intervention schemes for Chinese patients. Thus, this investigation aimed to describe the current state of exercise capacity as well as to identify its predictors in Chinese CAD patients after PCI or CABG.

2. Methods

2.1. Design

This is a retrospective study of patients undergoing PCI or CABG in a tertiary care medical institution in the mainland of China between January and October 2019.

2.2. Study population and setting

The subjects were patients with CAD after PCI or CABG performed in a single cardiovascular hospital in Beijing, China. The healthcare institution is a tertiary care hospital that caters to cardiovascular diseases and provides services to patients from all regions of China. The patients included in this study were referred to this cardiac rehabilitation center by cardiologists or cardiac surgeons. They had undergone cardiopulmonary exercise testing (CPET) using an incremental cycle ergometer as well as filled out questionnaires for evaluating symptoms of anxiety and depression. Informed consent was not obtained from the subjects as this investigation follows a retrospective study design. The inclusion criteria were as follows: diagnosed with CAD, underwent PCI or CABG, performed CPET, and with age ≥18 years. The exclusion criteria were any of the following: those with incomplete medical records (i.e. absence of sociodemographic characteristics, clinical history, CPET relevant parameters, or psychological data assessed by Self-Rating Anxiety Scale [SAS] and Self-Rating Depression Scale [SDS]).

2.3. Measurements

2.3.1. Cardiopulmonary exercise testing

A submaximal ergometer bicycle test (MasterScreen CPX, JAEGER, Germany) was used to assess exercise capacity. Each patient signed a written informed consent before the test. The
patients were asked to exercise until exhaustion (symptom-limited maximal test). A 3-min warm-up at 0 Watts was performed, and the workload was continuously increased by 5, 10, 15, or 20 Watts each minute until exhaustion. In this test, the patients were asked to maintain a 60-rpm pedaling cadence. Ventilation and gas exchange variables were continuously collected using connecting pipes and measured with a gas analyzer on a breath-by-breath basis. The system was calibrated prior to each test. Heart rate, 12-lead electrocardiogram (EKG), and SpO2 were continuously monitored. We measured blood pressure at 2-min intervals. The tests were terminated upon the development of symptoms, including chest tightness, leg fatigue, or dyspnea, or when the test supervisor detected warning signs such as desaturation, abnormal ECG presentation, or unstable vital signs. After the tests ceased, the patients were rated in terms of perceived exertion using the Borg Rating of Perceived Exertion (RPE) [34], which helps doctors judge the level of fatigue from CPET and correlate the degree of fatigue during testing with that experienced during daily activities [35].

Based on the statement of the American Thoracic Society (ATS)/American College of Chest Physicians (ACCP) on cardiopulmonary exercise testing, a decrease in exercise capacity is characterized by an < 84% peak VO2 of the predicted value [36]. The quality of effort was evaluated using the respiratory exchange ratio (RER), with maximal exercise defined as having a peak RER ≥ 1.10 [16].

2.3.2. Zung Self-Rating Anxiety Scale and Zung Self-Rating Depression Scale

SAS [37] and SDS [38] were utilized to assess the respective symptoms of anxiety and clinical depression. Each scale comprised 20 items, and each item was scored using a 4-point Likert scale (1–4). Some items were subjected to reverse scoring (i.e., from 4 down to 1). We generated final raw scores for every questionnaire by adding the item scores together between 20 and 80. SAS/SDS index scores were then computed by multiplying the raw score by 1.25. The final scores of both questionnaires were then used to classify anxiety/depression as follows: normal (<50), mild (50–59), moderate to marked major (60–69), and severe to extreme major (>70). The validity and reliability of the Chinese versions of SAS and SDS scales were confirmed by previous epidemiological surveys [39,40].

Other data extracted from medical records included sociodemographic characteristics (e.g., age, gender, and education level), as well as clinical history (e.g., left ventricular ejection fraction [LVEF], body mass index [BMI], smoking history, comorbidities, history of previous PCI or CABG, and time from surgery to CPET). LVEFs were assessed by cardiologists using transthoracic echocardiography during CPET evaluation. We utilized the STROBE checklist for reporting this investigation.

2.4. Data collection

The investigators collected data by reviewing the patients’ medical records at the time of their visits to the CR center. When patients come to the CR center, one-to-one interviews were conducted by a cardiologist to collect data on social demographic characteristics and clinical history. Patients completed SAS and SDS personally based on their emotional experiences in the past week. After that, the physiotherapist instructed patients to perform the CPET test and recorded the relevant parameters into the medical records.

2.5. Statistical analysis

Data analysis was performed using SPSS for Windows ver. 23.0 (IBM). Exercise capacity was dichotomized as reduced exercise capacity (peak VO2 ≤ 84% of predicted value) and normal exercise capacity (peak VO2 >84% of predicted value) suggested by the ATS [36]. Descriptive statistics were utilized to describe the characteristics of the patients. Continuous variables were expressed as the mean ± standard deviation (SD) and categorical variables as frequencies (percentages) in normal distributions, whereas non-normally distributed variables were expressed as the median and interquartile. We conducted intergroup comparisons of categorical variables using the chi-square test, Fisher’s exact test, or Mann-Whitney U test. The student’s t-test was used for continuous variables. Binary logistic regression analysis was performed to calculate odds ratios and determine independent factors that were related to the likelihood of exercise capacity. Statistical significance was set at $P < 0.05$.

2.6. Ethical considerations

Permission was obtained from the ethics committee of the Peking Union Medical College (No. 202024). The researcher assured the anonymity and confidentiality of patients’ information.

3. Results

3.1. Demographic characteristics of patients

The study population consisted of 230 patients, and their characteristics based on dichotomized peak VO2 values are shown in Table 1. The average age of the patients who participated in the study was 59.34 ± 9.17 years. Most of the patients were male (80.4%), attained high school education (30.4%), and had a history of CABG (92.2%). The most common comorbidities were hyperlipidemia (63.5%) and hypertension (60.4%), and 45.2% of the patients were current smokers. Mean LVEF was 60.79% ± 5.64%, mean body mass index was 25.20 ± 3.36 kg/m², and mean abdominal circumference was 94.40 ± 9.80 cm. The median time from surgery to CPET was 3 months.

Comparison of clinical history variables by exercise capacity demonstrated a significantly greater proportion of current smokers in the exercise capacity reduction group (46.6% vs. 0%, $P = 0.04$). There were no significant between-group differences in exercise capacity based on age, gender, educational level, history of PCI/CABG, LVEF, BMI, abdominal circumference, and other cardiovascular risk factors (i.e., hypertension, diabetes mellitus, and hyperlipidemia).

3.2. Exercise capacity in CAD patients after PCI or CABG

Among the total population, only 3.0% (7/230) of the patients had normal exercise capacity, which is defined as peak oxygen uptake > 84% of their predicted capacity, whereas 97% (223/230) of patients represented decreased exercise capacity. The mean percentage of predicted peak VO2 was 55.67% ± 12.60%, and mean peak VO2 was 14.79 ± 4.24 ml/(kg·min), corresponding to 4.23 ± 1.21 METs. Peak RER was 1.15 ± 0.12, reflecting maximal exercises. The most common cause for test termination was leg fatigue 97.4% (224/230). The results of the cardiopulmonary exercise test are presented in Table 2.

Patients in the reduced exercise capacity group demonstrated a significantly lower peak VO2, percentage of predicted peak VO2, metabolic equivalents, maximum workload, peak systolic blood pressure, and test duration than those in the exercise capacity normal group. There were no significant ($P > 0.05$) between-group differences for RER, resting systolic blood pressure, resting diastolic blood pressure, peak diastolic blood pressure, resting heart rate, VE/VCO2 slope, or RPE.
Table 1
Demographics of the samples (n = 230) and comparisons between patients with reduced exercise capacity and normal exercise capacity.

| Variable                              | Overall population (n = 230) | Exercise capacity reduction group (peak VO2 ≤ 84% of predicted value, n = 223) | Normal exercise capacity group (peak VO2 > 84% of predicted value, n = 7) | χ²/Φ² P |
|---------------------------------------|-----------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------|
| Age, years                            | 59.34 ± 9.17                | 59.28 ± 8.91                                                                  | 61.29 ± 16.36                                                              | −0.32a 0.758 |
| Gender                                |                             |                                                                                |                                                                            | 0.00b 1.000 |
| Male                                  | 185 (80.4)                  | 179 (80.3)                                                                    | 6 (85.7)                                                                   |       |
| Female                                | 45 (19.6)                   | 44 (19.7)                                                                     | 1 (14.3)                                                                   |       |
| Education                             |                             |                                                                                |                                                                            |       |
| Primary school or lower               | 36 (15.7)                   | 34 (15.2)                                                                     | 2 (28.6)                                                                   | 1.40 b 0.705 |
| Middle school                         | 63 (27.4)                   | 61 (27.4)                                                                     | 2 (28.6)                                                                   |       |
| High school                           | 70 (30.4)                   | 69 (30.9)                                                                     | 1 (14.3)                                                                   |       |
| Junior college or higher              | 61 (26.5)                   | 59 (26.5)                                                                     | 2 (28.6)                                                                   |       |
| Medical condition                     |                             |                                                                                |                                                                            |       |
| CABG                                  | 212 (92.2)                  | 207 (92.8)                                                                    | 5 (71.4)                                                                   |       |
| PCI                                   | 18 (7.8)                    | 16 (7.2)                                                                      | 2 (28.6)                                                                   |       |
| LVEF (%)                              | 60.79 ± 5.64                | 60.76 ± 5.68                                                                   | 61.36 ± 4.41                                                               | −0.50b 0.613 |
| Number of coronary stents/grafts      | 3 (2.4)                     | 3 (2.4)                                                                       | 3 (1.3)                                                                   | −1.10a 0.268 |
| Time from surgery to CPET             | 3 (3, 3)                    | 3 (3, 3)                                                                       | 3 (3, 3)                                                                   | −0.06c 0.951 |
| BMI (kg/m²)                           | 25.20 ± 3.36                | 25.15 ± 3.26                                                                   | 26.91 ± 5.83                                                               | −0.80a 0.454 |
| Abdominal circumference (cm)          | 94.40 ± 9.80                | 94.36 ± 9.50                                                                   | 95.59 ± 18.08                                                              | −0.17b 0.856 |
| Current smoking                       | 104 (45.2)                  | 104 (46.6)                                                                     | 0 (0)                                                                      | 4.22b 0.040 |
| Hypertension                          | 139 (60.4)                  | 134 (60.1)                                                                     | 5 (71.4)                                                                   | 0.04b 0.832 |
| Diabetes mellitus                     | 72 (31.3)                   | 70 (31.4)                                                                      | 2 (28.6)                                                                   | 0.00b 1.000 |
| Hyperlipidemia                         | 146 (63.5)                  | 140 (62.8)                                                                     | 6 (85.7)                                                                   | 0.70b 0.400 |

Note: Data are n (%), Mean ± SD, or Median (P25, P75). a t value; b Z value; c Fisher's exact test. BMI = body mass index. CABG = coronary artery bypass graft. CPET = cardiopulmonary exercise test. LVEF = left ventricular ejection fraction. PCI = percutaneous coronary intervention.

Table 2
Exercise capacity and other CPET characteristics of the global population and subgroups.

| Variable                              | Overall population (n = 230) | Exercise capacity reduction group (peak VO2 ≤ 84% of predicted value, n = 223) | Normal exercise capacity group (peak VO2 > 84% of predicted value, n = 7) | P |
|---------------------------------------|-----------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------|
| Peak VO2, ml/(kg min)                 | 14.79 ± 4.24                | 14.55 ± 3.67                                                                  | 22.97 ± 10.90                                                              | −5.05 <0.001 |
| Percentage of predicted peak VO2, %   | 55.67 ± 12.60               | 54.47 ± 10.67                                                                 | 93.43 ± 11.83                                                              | −9.48 <0.001 |
| METs                                  | 4.23 ± 1.21                 | 4.16 ± 1.05                                                                   | 6.39 ± 3.10                                                                | −5.04 <0.001 |
| Maximum workload, W                   | 94.28 ± 38.09               | 93.05 ± 35.03                                                                 | 133.57 ± 89.95                                                             | −2.81 0.005 |
| Respiratory exchange ratio            | 1.15 ± 0.12                 | 1.15 ± 0.12                                                                   | 1.13 ± 0.12                                                                | 0.39 0.690 |
| Resting SBP, mmHg                     | 123.70 ± 20.12              | 123.35 ± 19.93                                                                | 134.86 ± 24.47                                                             | −1.49 0.136 |
| Resting DBP, mmHg                     | 73.57 ± 10.71               | 73.75 ± 10.61                                                                 | 67.86 ± 13.26                                                              | 1.43 0.152 |
| Peak SBP, mmHg                        | 150.79 ± 24.74              | 150.03 ± 24.45                                                                | 175.00 ± 23.15                                                             | −2.66 0.029 |
| Peak DBP, mmHg                        | 78.34 ± 12.15               | 78.46 ± 12.22                                                                 | 74.43 ± 9.41                                                               | 0.86 0.389 |
| Resting HR, bpm                       | 72.80 ± 12.17               | 72.87 ± 12.32                                                                | 70.71 ± 5.47                                                               | 0.46 0.646 |
| Peak HR, bpm                          | 112.31 ± 20.94              | 112.00 ± 20.70                                                                | 122.43 ± 27.48                                                             | −1.30 0.195 |
| VE/VCO₂ slope                         | 35.32 ± 5.64                | 35.35 ± 5.68                                                                   | 34.36 ± 4.70                                                               | 0.45 0.648 |
| RPE                                   | 14 (13, 15)                 | 14 (13, 15)                                                                   | 14 (13, 14)                                                                | −0.28 0.773 |
| Test duration, s                      | 397.81 ± 120.32             | 391.36 ± 113.74                                                               | 603.29 ± 151.67                                                            | −4.80 <0.001 |
| Causes of test termination            |                             |                                                                                |                                                                            |       |
| Leg fatigue                           | 224 (97.4)                  | –                                                                            | –                                                                          |       |
| Shortness of breath                   | 1 (0.4)                     | –                                                                            | –                                                                          |       |
| Chest tightness                       | 1 (0.4)                     | –                                                                            | –                                                                          |       |
| Angina                                | 2 (0.9)                     | –                                                                            | –                                                                          |       |
| Reach maximal exercise criteria       | 2 (0.9)                     | –                                                                            | –                                                                          |       |

Note: Data are n (%), Mean ± SD, or Median (P25, P75). a t value. DBP = diastolic blood pressure. HR = heart rate. METs = metabolic equivalents. RPE = Ratings of Perceived Exertion. SBP = systolic blood pressure. VE = ventilation. VCO₂ = carbon dioxide output. VO₂ = oxygen uptake. CPET = cardiopulmonary exercise testing.

3.3. Anxiety and depression in patients

The results showed that the average score of the SAS was 39.87 ± 7.44. A total of 20 participants (8.7%) with SAS scores >50 points were identified with anxiety. The mean SDS score was 42.52 ± 11.34, and 63 participants (27.4%) with SDS scores >50 points were identified with depression. Patients with reduced exercise capacity showed significantly higher SAS and SDS scores. The scores of anxiety and depression in the two groups are summarized in Table 3.

3.4. Predictor variables to exercise capacity

Binary logistic regression analysis was conducted using reduced exercise capacity as the dependent variable and age, current smoking, SAS, SDS and peak SBP as independent variables.
Although age did not demonstrate a difference between the two groups, age was an important factor that influenced exercise capacity and was used as an independent variable in binary logistic regression. The data revealed that SAS (OR = 113.95% CI 1.01–1.32, p = 0.029) is an independent risk factor for reduced exercise capacity in CAD patients after PCI or CABG. Other independent variables were not related to decreased exercise capacity.

4. Discussion

Importantly, we determined that the majority (97.0%, 223/230) of CAD patients had impaired exercise capacity, which is relatively higher than a previous study [25]. They assessed 112 CAD patients after PCI and reported that 64.3% of patients represented decreased exercise capacity. Moreover, peak VO2 values in our sample were markedly lower than age-matched norms for healthy individuals [41] and lower than those in CAD patients in other studies [17]. Wang et al. [26] performed a retrospective study involving 136 CAD patients who underwent PCI in the mainland of China and reported higher mean values of peak VO2 (22 ml/kg-min). Our current findings also demonstrate that the mean value of METs was 4.23 ± 1.21, which was lower than previously published studies [26]. METs are also generally used to assess exercise capacity and a prognosticator of CAD. Ross et al. [42] suggested that among the patients with CVD, the least fit patients (≤6 METs) had more than 4-fold increased risk of all-cause mortality compared with the fittest. Nes et al. [43] indicated for each 1-MET increase in exercise capacity, cardiovascular mortality decreased by 21% in both men and women. Similarly, another study demonstrated that for each 1-MET increase in measured exercise capacity, the risk reduction for fatal CVD and nonfatal CVD in men was 17% and 10%, respectively, and the risk for fatal CVD and nonfatal CVD in women decreased by 5% and 23%, respectively [44]. We thus hypothesize that abnormal exercise capacity in CAD patients is related to chronotropic incompetence, disorders in lung mechanics, inspiratory muscle fatigue, ineffective gas exchange, abnormal metabolism of peripheral muscles, as well as “fear of exercising”. This is consistent with the views of Lavie et al. [45] and Delsart et al. [46].

In addition, this study assessed the relationship between clinical history and exercise capacity. Our chi-squared test results revealed an association between smoking history and reduced exercise capacity, whereas in the binary logistic model, it did not show a significant relationship with the decrease of exercise capacity, which is concordant with the findings of Wang et al. [26]. Ades et al. [17]. studied 2,896 patients with a recent acute cardiac event requiring hospitalization and similarly found that a recent or past history of smoking had no effect on exercise capacity, as measured by peak VO2, although absolute peak VO2 values in smokers were lower compared with those who never smoked. Similarly, Zeher et al. [41], conducted a systematic review of the correlates of cardiorespiratory fitness (CRF), expressed as peak VO2, which suggested that there was no association between smoking and CRF. However, this is not the case with Mesquita et al. [47], in which the authors found cigarette smoking as an independent predictor of impaired exercise capacity. Previous studies have indicated that possible factors associated with the negative effects of smoking on the exercise capacity of healthy subjects include peripheral muscle abnormalities [48], increased levels of pro-inflammatory markers [49], and faster deterioration in body composition [50]. Therefore, further studies examining the association of exercise capacity in CAD patients with smoking history are warranted.

The present study has determined that the average level of depression and anxiety in the SAS or SDS was lower than the cut-off scores for mild anxiety and depression. However, as assessed by SAS and SDS scores, over 9% of CAD patients after PCI or CABG showed mild or more severe anxiety, and more than 27% of patients displayed mild or more severe depression. However, Gu et al. [30] reported the prevalence of anxiety and depression symptoms that were measured by Hospital Anxiety and Depression Scale (HADS) in CAD patients three months after PCI was 44.7% and 20.2%, respectively. The discrepancies between earlier and present studies may be attributable to differences in measurement tools, characteristics of patients, and post-surgical time points. Furthermore, our study demonstrates that anxiety is a risk factor of peak VO2, indicating that higher anxiety levels are negatively correlated with exercise capacity. Similarly, Pelletier et al. [51] reported that CAD patients with anxiety disorders exhibit insufficient exercise capacity. Kazukauskiene et al. [52] examined the correlation of various mental distress factors to exercise capacity and similarly found that anxiety is negatively correlated with exercise capacity. A previous study [53] showed that the interaction between anxiety and exercise capacity might be described as a vicious cycle. The reduction in exercise capacity leads to decreased participation in social activities and social support, which further increases the patients’ sense of insecurity and anxiety. Increased anxiety may be followed by muscular atrophy and weight loss. Furthermore, anxiety has been shown to increase the inflammatory response in CAD patients. These factors mentioned above may affect the exercise capacity of a patient [54,55]. However, this is not the case with Egger et al. [28], which showed that higher anxiety levels were correlated with greater improvement in exercise capacity. These findings may be attributed to the fact that anxiety developing after a major life-threatening event or with more severe personality characteristics (e.g., excessive worrying or neuroticism) may act as motivators to more extensively engage in exercise. Hence, patients with higher anxiety levels post-PCI or -CABG exhibit higher exercise capacity. Another research reported that exercise capacity is not associated with anxiety [56]. The discrepancies in the findings of these studies can be explained by variations in the methodology employed in assessing anxiety and exercise capacity. More studies exploring whether this finding widely occurs in Chinese CAD patients are thus warranted. The correlation between anxiety and exercise capacity may influence treatment schemes for CAD patients post-PCI or -CABG [41]. Interventions to decrease anxiety may increase exercise capacity in CAD patients. For instance, exercises (i.e. aerobic exercise or resistance exercise) have emerged as an efficacious treatment for anxiety symptoms [57]. Moreover, behavioral therapy (BT) (i.e., cognitive behavioral therapy,
interpersonal therapy, and counseling) is a common treatment for anxiety [58].

4.1. Implications for practice

The results suggest that healthcare professionals should assess exercise capacity in CAD patients after PCI or CABG. Attempts to improve exercise capacity should focus on improving symptoms of anxiety. Exercise therapy, which is consistently identified as the crucial component of a CR program, was recommended to the healthcare providers to alleviate symptoms of anxiety and improve exercise capacity.

4.2. Limitations

To our knowledge, this is one of the few studies that have focused on exercise capacity and its related factors in patients after CABG. However, this study has several limitations that should be considered. First, generalization of the findings of this study is limited as the data were collected only from one CR center, possibly leading to selection bias. Second, this was a retrospective study, and thus we could only use data that were already available. Some clinical covariates could not be obtained, such as data on comorbidities, including peripheral vascular disease, obstructive lung disease, or arthritis, each of which could negatively affect exercise capacity. Future research would be optimized using important variables and associations by prospective studies rather than pre-determined data. In addition, studies are needed that enroll larger samples from multi-centers of diverse regions in the mainland of China.

5. Conclusion

This study demonstrates that 97.0% of Chinese CAD patients post-PCI or -CABG have impaired exercise capacity. Healthcare providers should thus pay more attention to exercise capacity in patients after PCI or CABG. In addition, we observed a significant association between anxiety and reduced exercise capacity. Additional intervention research should thus be conducted to improve patient anxiety and recommend an exercise regimen based on CPET to improve exercise capacity.

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CRediT authorship contribution statement

Ying Li: Writing – original draft, Data curation. Xue Feng: Supervision, Writing – review & editing. Biyun Chen: Investigation. Huaping Liu: Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnss.2021.05.008.

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