Original Artikel

Factor Associated with Improvement of VO2 Max after Cardiac Rehabilitation in Patients with Coronary Artery Disease Post Revascularization

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ABSTRACT

Aims: This study aimed to assess the association of cardiovascular risk factors and the number of risk factors with improvement of VO2 Max in patients with coronary artery disease (CAD) post-revascularization by Coronary Artery Bypass Graft (CABG) and Percutaneous Coronary Intervention (PCI) after completing phase II cardiac rehabilitation (CR).

Methods: This was an analytic study with a cross-sectional design. Data were taken retrospectively using secondary data from medical records. The study population was post-revascularization CAD patients who underwent phase II CR at RSUP Dr. Hasan Sadikin Bandung in 2019-2020, and samples were taken by total sampling method. Data were processed with Microsoft Excel 2016 and Statistical Software R version 4.0.0, then presented analytically. The characteristics were described based on age, sex, body mass index, education, occupation, and the number of risk factors. Characteristic data were grouped based on the CABG and PCI interventions obtained. Correlation analysis was conducted to assess the association of age, family history, physical inactivity, smoking, obesity, hypertension, dyslipidemia, and diabetes mellitus risk factors and the number of risk factors with VO2 Max. Data were analyzed with appropriate statistical tests.

Results: The median (range) of improvement of VO2 Max was 6.00 (1.20, 17.73) (ml/kg/min). Smoking was significantly associated with an improvement of VO2 Max (p-value 0.0197), while age, family history, physical inactivity, obesity, hypertension, dyslipidemia, and diabetes mellitus were not. Patients with a total of seven risk factors had the highest improvement of VO2 Max with 12.88 (3.15, 12.90) (ml/kg/minute), followed by patients with a total of six risk factors with 9.84 (1.80, 16.44) (ml/kg/minute). However, the number of risk factors had no significant association with the improvement of VO2 Max.

Conclusion: Smoking as a CVD risk factor was associated with improvement of VO2 Max, while age, family history, physical inactivity, obesity, hypertension, dyslipidemia, and diabetes mellitus were not. The number of risk factors had no significant association with the improvement of VO2 Max.

Keywords: Body Mass Index, Coronary Artery Disease, Cardiac Rehabilitation, Cardiovascular Diseases, Percutaneous Coronary Intervention, Sedentary Behavior

ABSTRAK

Tujuan: Penelitian ini bertujuan untuk menilai hubungan faktor risiko kardiovaskular dan jumlah faktor risiko dengan peningkatan VO2 Max pada pasien penyakit arteri koroner (PAK) pasca revaskularisasi dengan *Coronary Artery Bypass Graft* (CABG) dan *Percutaneus Coronary Intervention* (PCI) setelah menyelesaikan rehabilitasi jantung (RJ) fase II.

Metode: Penelitian ini bersifat analitik dengan desain *cross-sectional*. Data diambil secara retrospektif dengan menggunakan data sekunder dari rekam medis. Populasi penelitian adalah pasien PAK pasca revaskularisasi yang menjalani RJ fase II di RSUP Dr. Hasan Sadikin Bandung tahun 2019-2020, dan sampel diambil dengan metode total sampling. Data diolah dengan *Microsoft Excel* 2016 dan *Statistical Software R* versi 4.0.0, kemudian disajikan secara analitis. Karakteristiknya dijelaskan berdasarkan usia, jenis kelamin, indeks massa tubuh, pendidikan, pekerjaan, dan jumlah faktor risiko. Data karakteristik dikelompokkan berdasarkan intervensi CABG dan PCI yang diperoleh. Analisis korelasi dilakukan untuk menilai hubungan faktor risiko usia, riwayat keluarga, kurang aktivitas fisik, merokok, obesitas, hipertensi, dislipidemia, dan diabetes melitus serta jumlah faktor risiko dengan VO2 Max. Data dianalisis dengan uji statistik yang sesuai.

Hasil: Median (kisaran) peningkatan VO2 Max adalah 6,00 (1,20, 17,73) (ml/kg/menit). Merokok berhubungan signifikan dengan peningkatan VO2 Max (p-value 0,0197), sedangkan usia, riwayat keluarga, kurang aktivitas fisik, obesitas, hipertensi, dislipidemia, dan diabetes melitus tidak berhubungan signifikan. Pasien dengan total tujuh faktor risiko memiliki peningkatan VO2 Max tertinggi yaitu 12,88 (3,15, 12,90) (ml/kg/menit), disusul pasien dengan total enam faktor risiko dengan 9,84 (1,80, 16,44) (ml/ kg/menit). Namun jumlah faktor risiko tidak mempunyai hubungan bermakna dengan peningkatan VO2 Max.

Kesimpulan: Merokok sebagai faktor risiko penyakit kardiovaskular berhubungan dengan peningkatan VO2 Max, sedangkan usia, riwayat keluarga, kurang aktivitas fisik, obesitas, hipertensi, dislipidemia, dan diabetes melitus tidak berhubungan. Banyaknya faktor risiko tidak mempunyai hubungan bermakna dengan peningkatan VO2 Max.

Kata Kunci: Indeks Massa Tubuh, Penyakit Arteri Koroner, Penyakit Kardiovaskular, Perilaku Sedenter, Rehabilitasi Jantung

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INTRODUCTION

Coronary Artery Disease (CAD) is the worldwide leading cause of death in all age groups. In 2018, the World Health Organization (WHO) reported the number of deaths due to CAD in Indonesia had reached 318,820 or 18.73% of the total deaths.[1] Based on a physician's diagnosis, in 2013, the prevalence of CAD in Indonesia was 0.5% or an estimated 883,447 people. The highest prevalence was in West Java Province.[2]

The pathophysiological mechanism underlying the occurrence of CAD is atherosclerosis. Atherosclerosis is a process of thickening and hardening of blood vessels due to inflammatory reactions in blood vessel walls, which narrow the lumen.[3] Narrowing or blockage of the coronary artery results in an

imbalance of oxygen and nutritional supplies of the heart muscle. The reduction of blood flow due to the blockage (ischemic state) caused angina-type chest pain. Complete blockage due to thrombus of the ruptured atherosclerotic plaque caused a complete or partial occlusion of distal heart vessels, then the infarct occurred.[4]

Accumulation of risk factors induced the formation of atherosclerosis. Risk factors are generally divided into modifiable and non-modifiable risk factors. Modifiable risk factors include hypertension, diabetes mellitus, obesity, smoking, dyslipidemia, unhealthy diet, and physical inactivity. The non-modifiable risk factors are age, sex, ethnicity, and family history.[5] Data suggested the substantial burden of modifiable cardiovascular risk factors contributed to the high burden of CVD in Indonesia. About 65% of men were active smokers, 30% had been diagnosed with high cholesterol, 23% had uncontrolled hypertension, 20% were overweight, and 6% had diabetes. About 2% of women were smokers, 40% had high cholesterol, 29% had hypertension, 33% were overweight, and 8% had diabetes.[6]

A coronary revascularization procedure is a medical intervention to remove the blockage or widen the coronary arteries. Coronary Artery Bypass Graft (CABG) surgery is recommended as standard treatment for CAD. The Percutaneous Coronary Intervention (PCI) was developed as an alternative to CABG as it is less invasive and more favorable.[7] Revascularization procedures are effective in relieving symptoms of severe angina and reducing mortality rate, but there are complications of every medical procedure, especially without lifestyle modification. The complications are myocardial infarction, stroke, arrhythmia, and death due to the CABG procedure, and the risk of restenosis due to the PCI procedure.[8]

Cardiac rehabilitation (CR) is a program to promote secondary prevention. It is a major component of the management of all patients with CAD. The CR program includes physical exercise and social and psychological interventions aimed at reducing CVD risk factors and disease progression and maintaining patients' activities and participation in the community. Phase II CR is an advanced program from the acute period (phase I). Phase II CR is given as a supervised exercise program at the hospital, and continued to a community-based maintenance program to improve long-term adherence towards exercise and a healthy lifestyle (phase III).[9]

The American Heart Association and American College of Cardiology recommended CR programs not only for patients with post-myocardial infarction or coronary revascularization but also for patients with stable angina. CR program, as the class I recommendation, has been established to increase functional capacity, reduce mortality rate, decrease one-year hospitalization rate, improve health-related quality of life, and suppress the cost of health care resources in patients with CAD including post-coronary revascularization patients.[9,10]

Functional capacity is the maximum capacity of a person to perform activities and is expressed in metabolic equivalent (MET). The maximum capacity for aerobic activity is determined by the maximum oxygen consumption (VO2 Max) which is the product of cardiac output and the arterial-venous oxygen difference. VO2 Max values are usually achieved by exercises involving large muscles, which are about half of the total body muscles. VO2 Max values are affected by age, sex, fitness status, and the presence of disease or medications that affect the components.[11]

Improvement in functional capacity is the main clinical outcome of phase II CR as functional capacity is one of the key factors in secondary prevention of CVD. Coronary revascularization procedure negatively affects the functional capacity of the patient, which leads to a sedentary lifestyle. Submaximal training test including the 6-minute-walk test (6MWT) frequently applied to evaluate

functional capacity. This test is implemented before and after phase II CR.[12] Low functional capacity is associated with a higher risk of CVD and death from all causes. Conversely, higher functional capacity is proven to diminish the mortality rate. Some studies are still contradictive about the effect of functional capacity on cardiovascular risk. There is ample epidemiological and clinical evidence suggesting that functional capacity is a stronger predictor of mortality than other risk factors. In addition, lower functional capacity, in conjunction with the presence of other risk factors increases the risk of adverse events.[13] Another study has reported that age, gender, waist circumference, the difference between resting pulse and maximal heart rate, and smoking were the most important factors associated with VO2 Max, while systolic and diastolic blood pressure were not.[14]

This study aimed to assess the association of cardiovascular risk factors and the number of risk factors with improvement of VO2 Max in patients with CAD post-revascularization by CABG and PCI after completing phase II CR at Dr. Hasan Sadikin General Hospital Bandung (RSHS). This study also aimed to describe the improvement of VO2 Max in each risk factor group and outcome pattern in multiple risk factors.

METHOD

This was a retrospective cross-sectional analytical study. The study was done after obtaining approval from the Research Ethics Committee of the Faculty of Medicine Padjadjaran University No. 1411/UN6.KEP/EC/2019. The study was conducted from September 2019 to March 2020 using secondary data from medical records. The population was post-revascularization CAD patients with CABG and PCI methods after completing phase II CR at RSHS in 2019-2020. The inclusion criteria were CAD patients who underwent revascularization after phase II CR at RSHS from 1 September 2019 to 29 February 2020. Subjects were excluded if there were no data

on VO2 Max before and after phase II CR or if their medical records could not be accessed. All medical records that met the inclusion and exclusion criteria were included.

There were eight risk factors assessed in this study. Age and physical inactivity risk factors were defined based on criteria in the American College of Sports Medicine. Age is considered a risk factor for men aged $\geq$45 years and women $\geq$55 years. Physical inactivity is defined as an individual not doing regular physical activity at a minimum of moderate intensity for a minimum of 30 minutes three times a week in the last three months. Obesity was defined as body mass index $\geq$30 kg/m2.[15]

Data were processed with Microsoft Excel 2016 and Statistical Software R 4.0.0 version and then presented analytically. Subject characteristics were presented as age, sex, body mass index, education, occupation, and the number of risk factors. Furthermore, the data were classified based on the type of revascularization performed, CABG or PCI. Risk factors assessed were age, family history, physical inactivity, smoking, obesity, hypertension, dyslipidemia, and diabetes mellitus. VO2 Max values at the pre-rehabilitation, post-rehabilitation, and improvement results were presented in median and range (minimal, maximal). VO2 Max value was obtained from the conversion of a 6-minute walk distance using the Cahalin formula.

Each risk factor was assessed in the normality test (Kolmogrov-Smirnov Test) and then analyzed using the Mann-Whitney test and Fisher's Method. A significant difference in the median between those having risk factors and those without risk factors was described. The correlation between the number of risk factors and improvement of VO2 Max was analyzed using the normality test (Kolmogrov-Smirnov Test) and then analyzed by the Spearman correlation test. All statistical tests were carried out with a significance level of 0.05.

RESULTS

Of the total 96 study population, 71 subjects (76.3%) met the inclusion and exclusion criteria. The study subjects were dominated by patients revascularized with CABG, aged 55-64 years, male, obesity class 1 (BMI was 25-29.9), history of diploma education or higher, and worked as entrepreneurs (Table 1).

Table 2 shows the VO2 Max values after coronary revascularization for each risk factor. Median VO2 Max values before and after undergoing phase II CR were 16.22 (9.44, 23.48) (ml/kg/min) and 21.98 (12.86, 38.78) (ml/kg/min). The highest improvement of VO2 Max was 7.35 (1.59, 17.73) (ml/kg/min), while the lowest was 4.70 (1.20, 16.05) (ml/kg/min) with an overall improvement of 6.00 (1.20, 17.73) (ml/kg/min). Subjects with age, family history, smoking, and physical inactivity risk factors had a lower VO2 Max value at the beginning of CR compared to subjects without these risk factors. Improvement of VO2 Max.

Patients with seven risk factors had the highest improvement of VO2 Max of 12.88 (3.15, 12.90) (ml/kg/min). Data on VO2 Max improvement based on the number of risk factors can be seen in Table 3.

Smoking is significantly associated with the improvement of VO2 Max (p-value of 0.0197). Other risk factors did not show a median difference (Table 4). The number of risk factors has no significant association with the improvement of VO2 Max (Table 5).

Table 1. Characteristics of Study Subjects

Characteristics	Number of Subjects n (%)		
	CABG	**PCI**	**Total**
	55 (77.5%)	16 (22.5%)	71 (100%)
Age (years), n (%)			
35-44	3 (5.4%)	4 (25%)	7 (9.9%)
45-54	15 (27.3%)	2 (12.5%)	17 (23.9%)
55-64	21 (38.2%)	6 (37.5%)	27 (38%)
65-75	16 (29.1%)	2 (12.5%)	18 (25.4%)
75+	0 (0%)	2 (12.5%)	2 (2.8%)
Sex, n (%)			
Male	49 (89.1%)	14 (87.5%)	63 (88.7%)
Female	6 (10.9%)	2 (12.5%)	8 (11.3%)
BMI, n (%)			
Underweight (<18.5)	1 (1.8%)	1 (6.3%)	2 (2.8%)
Normal (18.5-22.9)	12 (21.8%)	5 (31.2%	17 (23.9%)
Overweight (23-24.9)	11 (20%)	6 (37.5%)	17 (23.9%)
Obese 1 (25-29.9)	30 (54.6%)	4 (25%)	34 (48%)
Obese 2 (>30)	1 (1.8%)	0 (0%)	1 (1.4%)
Education, n (%)			
Primary School	0 (0%)	0 (0%)	0 (0%)
Junior High School	2 (3.6%)	0 (0%)	2 (2.8%)
Senior High School	20 (36.4%)	5 (31.3%)	25 (35.2%)
Diploma or higher	33 (60%)	11 (68.7%)	44 (62%)
Occupation, n (%)			
Goverment employees	14 (25.5%)	2 (12.5%)	16 (22.5%)
General employees	7 (12.7%)	2 (12.5%)	9 (12.7%)
Police/Military	0 (0%)	0 (0%)	0 (0%)
Entrepeneur	16 (29.1%)	6 (37.5%)	22 (30.1%)
Retired	14 (25.5%)	5 (31.3%)	19 (26.8%)
Housewife	1 (1.8%)	1 (6.3%)	2 (2.8%)
Another	3 (5.4%)	0 (0%)	3 (4.2%)
Jobless	0 (0%)	0 (0%)	0 (0%)
Number of Risk Factor, n (%)			
0	0 (0%)	1 (6.3%)	1 (1.4%)
1	2 (3.6%)	0 (0%)	2 (2.8%)
2	4 (7.2%)	0 (0%)	4 (5.6%)
3	7 (12.7%)	2 (12.5%)	9 (12.7%)
4	19 (34.5%)	5 (31.3%)	24 (33.8%)
5	18 (32.7%)	5 (31.3%)	23 (32.4%)
6	3 (5.4%)	2 (12.5%)	5 (7%)
7	2 (3.6%)	1 (6.3%)	3 (4.2%)
8	0 (0%)	0 (0%)	0 (0%)

Table 2. Overview of VO2 Max Values of Subjects Based on Risk Factors

Risk Factors	n	VO2 Max (ml/kg/minutes)		
		Before	After	Improvement
		Med (Min, Max)	Med (Min, Max)	Med (Min, Max)
Age (men ≥45 years, women ≥55 years)				
Yes	63	16.00 (9.44, 23.48)	21.98 (12.86, 38.78)	5.79 (1.20, 17.73)
No	8	17.15 (12.08, 23.48)	22.13 (17.48, 33.98)	6.89 (1.40, 10.50)
Family History				
Yes	34	16.11 (9.44, 23.48)	20.87 (12.86, 33.98)	4.84 (1.20, 16.44)
No	37	16.58 (11.50, 22.73)	24.20 (15.70, 38.78)	7.35 (1.59, 17.73)
Smoking History				
Yes	40	14.96 (11.50, 23.48)	22.73 (15.70, 34.00)	7.35 (1.80, 17.73)
No	31	16.85 (9.44, 23.48)	21.35 (12.86, 38.78)	4.70 (1.20, 16.05)
Physical Inactivity				
Yes	57	15.32 (9.44, 23.48)	21.53 (12.86, 38.78)	5.79 (1.40, 17.73)
No	14	17.69 (10.13, 23.48)	24.41 (13.58, 34.00)	6.36 (1.20, 12.00)
Obesity				
Yes	35	16.60 (9.44, 23.48)	21.98 (12.86, 38.78)	6.15 (1.20, 16.41)
No	36	15.64 (10.13, 20.00)	21.91 (13.43, 30.68)	5.90 (1.40, 17.73)
Hypertension				
Yes	40	16.94 (10.13, 23.48)	23.24 (13.58, 38.78)	6.35 (1.20, 17.73)
No	31	15.11 (9.44, 22.00)	20.20 (12.86, 34.00)	5.79 (1.59, 12.80)
Dyslipidemia				
Yes	32	16.29 (11.48, 23.48)	21.76 (14.99, 33.98)	5.59 (1.40, 12.90)
No	39	16.22 (9.44, 23.48)	22.28 (12.86, 38.78)	6.15 (1.20, 17.73)
Diabetes Mellitus				
Yes	7	17.78 (11.50, 22.73)	26.93 (15.70, 38.78)	7.35 (3.30, 16.44)
No	64	16.11 (9.44, 23.48)	21.80 (12.86, 34.00)	5.78 (1.20, 17.73)
Total	**71**	**16.22 (9.44, 23.48)**	**21.98 (12.86, 38.78)**	**6.00 (1.20, 17.73)**

Table 3. VO2 Max Overview of Post-Revascularization Patients Based on the Number of Risk Factors

Number of Risk Factors	n	VO2 Max (ml/kg/minutes)		
		Before	After	Improvement
		Med (Min, Max)	Med (Min, Max)	Med (Min, Max)
0	1	17.00 (17.00, 17.00)	24.62 (24.62, 24.62)	7.62 (7.62, 7.62)
1	2	18.86 (17.72, 20.00)	26.74 (24.08, 29.39)	7.86 (6.36, 9.39)
2	4	17.48 (16.22, 18.89)	25.43 (18.89, 34.00)	8.49 (1.59, 12.00)
3	9	15.10 (10.13, 22.00)	20.20 (13.43, 34.00)	3.60 (2.73, 12.00)
4	24	14.71 (9.44, 23.48)	20.20 (12.86, 30.10)	4.70 (1.20, 17.73)
5	23	15.95 (11.48, 22.73)	22.28 (14.99, 38.78)	6.33 (1.80, 16.41)
6	5	18.40 (13.22, 23.48)	26.93 (20.20, 33.98)	9.84 (1.80, 16.44)
7	3	17.20 (17.20, 18.38)	30.08 (21.53, 30.10)	12.88 (3.15, 12.90)
8	0	0	0	0

Table 4. Association of Cardiovascular Risk Factors with Improvement of VO2 Max in Post-Revascularization Patients

Risk Factor	n	VO2 Max (ml/kg/minutes)			Mann Whitney Test (α=0.05)
		Before	After	Improvement	
		Med (Min, Max)	Med (Min, Max)	Med (Min, Max)	p-value
Age (men ≥45 years, women ≥55 years)*					
Yes	63	16.00 (9.44, 23.48)	21.98 (12.86, 38.78)	5.79 (1.20, 17.73)	0.7434
No	8	17.15 (12.08, 23.48)	22.13 (17.48, 33.98)	6.89 (1.40, 10.50)	0.7101*
Family History					
Yes	34	16.11 (9.44, 23.48)	20.87 (12.86, 33.98)	4.84 (1.20, 16.44)	0.1161
No	37	16.58 (11.50, 22.73)	24.20 (15.70, 38.78)	7.35 (1.59, 17.73)	
Smoking History					
Yes	40	14.96 (11.50, 23.48)	22.73 (15.70, 34.00)	7.35 (1.80, 17.73)	0.0197
No	31	16.85 (9.44, 23.48)	21.35 (12.86, 38.78)	4.70 (1.20, 16.05)	
Physical Inactivity					
Yes	57	15.32 (9.44, 23.48)	21.53 (12.86, 38.78)	5.79 (1.40, 17.73)	0.5729
No	14	17.69 (10.13, 23.48)	24.41 (13.58, 34.00)	6.36 (1.20, 12.00)	
Obesity					
Yes	35	16.60 (9.44, 23.48)	21.98 (12.86, 38.78)	6.15 (1.20, 16.41)	0.6413
No	36	15.64 (10.13, 20.00)	21.91 (13.43, 30.68)	5.90 (1.40, 17.73)	
Hypertension					
Yes	40	16.94 (10.13, 23.48)	23.24 (13.58, 38.78)	6.35 (1.20, 17.73)	0.4070
No	31	15.11 (9.44, 22.00)	20.20 (12.86, 34.00)	5.79 (1.59, 12.80)	
Dyslipidemia					
Yes	32	16.29 (11.48, 23.48)	21.76 (14.99, 33.98)	5.59 (1.40, 12.90)	0.6438
No	39	16.22 (9.44, 23.48)	22.28 (12.86, 38.78)	6.15 (1.20, 17.73)	
Diabetes Mellitus*					
Yes	7	17.78 (11.50, 22.73)	26.93 (15.70, 38.78)	7.35 (3.30, 16.44)	0.2470*
No	64	16.11 (9.44, 23.48)	21.80 (12.86, 34.00)	5.78 (1.20, 17.73)	

Note: *Using Fisher's Method Test, because one of the sample amounts was <10

Table 5. Association of the Number of Risk Factors with Improvement of VO2 Max in Post-Revascularization Patients

	Spearman Test	
	p-value	Rho
The Number of Risk Factors Improvement of VO2 Max	0.2166	0.1484741

DISCUSSION

This study assessed the association between cardiovascular risk factors and improvement of VO2 Max in post-coronary revascularization patients with CABG and PCI methods after completing phase II CR. It was found that improvement of VO2 Max was 6.00 (1.20, 17.73) (ml/kg/min). This result was higher than that obtained by Hayta and Korkmaz with 2.9 ± 2.3 (ml/kg/min) average improvement of VO2 Max in post-CABG patients who underwent CR.[16] In heart failure patients, a combination of exercise in phase II CR improvement of VO2 Max by 2.16 (ml/kg/min). The increase was higher in longer duration and higher intensity exercise programs.[17]

Aerobic exercise increases cardiorespiratory fitness by improving cardiac efficiency and reducing myocardial oxygen demand. During exercise, coronary blood flow increases to fulfill the demand. This mechanism relies on coronary arteriolar vasodilation, a process that is limited by the presence of CAD. Endothelial dysfunction is the underlying mechanism that results in inadequate coronary vasodilation and low perfusion pressure at the distal of the stenotic coronary arteries. Physical exercises can improve endothelial function, attenuate vasoconstriction, and increase the production of nitric oxide as well as microvasculature sensitization to vasodilation.[18]

In this study, we found that patients with seven risk factors had the highest improvement of VO2 Max, followed by patients with six risk factors. More risk factors result in higher improvement of VO2 Max, but statistical tests did not find any association between the number of cardiovascular risk factors and improvement of VO2 Max. One study showed that a higher VO2 Max value was associated with a lower risk of CAD in Swedish young adults.[19] Individuals with multiple cardiovascular risks have low VO2 Max, so the increase in VO2 Max after undergoing CR is more significant due to the physiological adaptation of the cardiorespiratory as a result of exercise.[20]

The present study revealed that of all cardiovascular risk factors, only smoking was significantly associated with improvement of VO2 Max (p-value 0.0197). However, the form of association could not be further identified due to limited data and research methods. Many studies explored the association between each risk factor with VO2 Max values, but there was limited study that assessed the association between risk factors and improvement of VO2 Max values after phase II CR.[14,21,22] Tiksnadi et al. found that increased functional capacity after completion of CR program was not associated with diabetes mellitus, hypertension, dyslipidemia, smoking history, and type of procedure given.[21] Kind et al. identified that gender, waist circumference, difference in maximal resting heart rate, smoking, and age were associated with VO2 Max, while systolic and diastolic blood pressure were not.[14]

Research by Putra et al. found that VO2 Max in the active smoking population was lower than that of non-smokers. This occurs because hemoglobin has a greater affinity to carbon monoxide. In exercise sessions, a

smoker is likely to gasp for air to meet an optimal demand.[22]

Previous research found a negative relationship between smoking and cardiorespiratory fitness, where smokers showed low cardiorespiratory fitness.[23,24] The negative impact of smoking on the cardiovascular and neurological systems, both systems needed for physical activity, reduces performance in activities and sports. Smoking can increase carbon monoxide levels which causes a decrease in the oxygen levels carried by hemoglobin. [25] Furthermore, nicotine contained in cigarettes can also causes increased sympathetic nerve activity which will increase epinephrine in plasma and acutely increase cardiac workload by stimulating heart rate, blood pressure, and myocardial contractility. These all can lead to increase in peripheral resistance which causes decreased blood flow to the tissues.[26]

Cardiovascular risk factors induced the formation of atherosclerosis in the blood vessels leading to stiffness of the vessel walls. The stiffness of the blood vessel walls further affected the body's adaptation to aerobic exercise thus affecting the VO2 Max value.[27] Research by Kim et al. found that the older the person, the lower the VO2 Max. Decreased heart rate and cardiac output due to the aging process are the main reasons.[28] Deterioration of physical fitness level will accelerate after the age of 30 years and will decrease with increasing physical activity, maintaining body weight, quitting smoking, and not consuming alcohol.[29]

By this, other studies claimed that physical activity will induce heart and lung adaptations to increase cardiac output and maintain oxygen demand in muscles throughout the body. In patients with obesity and dyslipidemia, the amount of adipose tissue and cholesterol in the body accompanied by high levels of leptin in the blood will trigger cellular nitric oxide production to induce cardiomyocyte contractions and lowering muscle oxygen supply.[30]

According to Tayade et al., type 2 diabetes mellitus was significantly associated with lower VO2 Max. This is related to high glycolytic and low oxidative enzymes, where the difference in the ratio of the two enzymes will affect the speed of the cell oxidation process.[31] Adaptation in hypertensive patients results in higher pressure on the heart muscle, thus affecting the heart rate, cardiac output, and VO2 Max value. Exercise will ameliorate the VO2 Max adaptation in hypertensive patients.[32]

Yang et al. reported that exercise in post-PCI patients will be beneficial in reducing ischemia by angiogenesis and increasing endothelial function. Exercise activates regeneration, stimulates the production of endogenous neurohormones and various natural health restoration mechanisms to increase collateral circulation, and simultaneously increases activity tolerance. Exercise improves coronary blood flow reserve capacity and cardiovascular work efficiency to accelerate physical recovery and prevent the occurrence of angina.[20]

Aerobic exercise in phase II CR improves cardiorespiratory fitness, despite that exercise may not inhibit the development of atherosclerosis and vascular inflammatory process or stabilize atherosclerotic plaques.[20] Implementation of community-based preventive strategies is believed to reduce cardiovascular risk factors, especially high blood pressure and total cholesterol or smoking.[6]

There were several limitations of this study. Firstly, the retrospective data collection based on medical records could not specifically assess the association of smoking risk factors with the improvement of VO2 Max. Secondly, the collection of data from one hospital prevented a representative result. Thirdly, the ignorance of the patient's lifestyle and medication may affect the VO2 Max value at the time of measurement. A cohort study providing a complete overview of the patient's course of rehabilitation and life is needed.

CONCLUSIONS

Smoking was associated with improvement of VO2 Max, while age, family history, physical inactivity, obesity, hypertension, dyslipidemia, and diabetes mellitus were not. Patients with seven risk factors had the highest improvement of VO2 Max, but the number of risk factors was not significantly associated with improvement of VO2 Max.

CONFLICTS OF INTEREST

The authors have nothing to declare.

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