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Is there a Place for the Fullerton Test in Evaluation of Heart Failure Patients? The Relationship between Exertional Gas Exchange Parameters and Functional Fitness in Patients with Heart Failure: A Pilot Study

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Abstract

Background: To minimize the effect of heart failure (HF) on quality of life and to reduce the economic burden, it is necessary to provide means of rehabilitation and prognosis evaluation for patients. Patients with severe HF might not be able to perform the most commonly used cardiopulmonary exercise test (CPET), even using the easiest protocols. The Fullerton functional fitness test, developed for the elderly, might be suitable for evaluation of such patients. Our aim was to determine relationship between functional fitness and exertional gas exchange parameters in HF patients, and if they performed worse in functional fitness tests than patients without HF.

Methods: Twenty-one male patients were included in this prospective registry; twelve with HF and nine without. They underwent the standard Fullerton test; the six-minute-walk test (6MWT; patient walks for six minutes along a corridor, and the distance covered is measured; it is a submaximal exercise test for healthy individuals) was modified by using a portable CPET device to record exertional gas exchange parameters.

Results: The HF patients had lower left ventricular ejection fraction and were younger; they presented significantly worse "chair sit-and-reach" results (-0.18 vs. 1.81 cm, p=0.041) and 6-minute walking distance (334.8 vs. 508.4 m, p=0.002), less exercise repetitions in "chair stand" (10.7 vs. 15.1, p<0.001) and "arm curl" (13 vs. 16.8, p<0.001), longer time to perform "8-foot up-and-go" (7.1 vs. 5.6 s, p=0.030), higher VE/VCO_2 slope (34.1 vs. 29, p=0.005), and tended to present lower peak oxygen uptake parameters (VO_2/kg 11.8 vs. 14, p=0.13; VO_2 0.99 vs. 1.22, p=0.10; VO_2 as percentage of predicted 43.1 vs. 55.4, p=0.14). 6 MWT, "chair stand" and "arm curl" showed the strongest correlations with AT VE/VCO_2 (r=-0.58, p=0.006; r=-0.57, p=0.007; r=-0.62, p=0.003 respectively) and VE/VCO_2 slope (r=-0.60, p=0.004; r=-0.52, p=0.015; r=-0.50, p=0.021 respectively) and VO_2 as percentage of predicted (r=0.59, p=0.005; r=0.55, p=0.009; r=0.47, p=0.031 respectively); 6MWT correlated strongly with VO_2/kg (r=0.61, p=0.004).

Conclusion: HF patients perform worse in the Fullerton test than patients without HF. Physical fitness is related to CPET parameters taken during 6MWT. Lower physical fitness is related to lower exercise capacity and worse ventilatory efficiency. The Fullerton test may be useful in complex evaluation of HF patients.

Keywords: Physical fitness, Heart failure, Fullerton test, Cardio-pulmonary exercise testing

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Introduction

Heart failure (HF) is one of the major health issues in modern societies, causing a considerable number of hospitalizations and deaths each year. It may be compared to cancer due to a similarly poor prognosis and high mortality [1]. It is connected with a substantial decrease of life quality [2]; it has been shown to have a greater impact on the patients' lives than other chronic diseases [3], and it generates much costs for the health care system because of multiple and prolonged hospitalizations [4]. Studies show that young, not-yet-retired HF patients rarely perform professional activities because of the HF induced disability [5].

The gold standard in evaluation of HF patients is cardiopulmonary exercise testing (CPET) using a treadmill or a cycloergometer [6]. However, patients with severe HF encounter significant limitations to their daily activities; many of them lead sedentary lifestyles, and they might not be able to perform a CPET, even using the easiest protocols. The Fullerton functional fitness test was developed to evaluate community-residing older adults, i.e. between 60 and 90 years old and older [7,8]. It allows assessment of ability to be self-dependent, risk of injury and falling down, and monitoring of treatment and rehabilitation. It includes items to evaluate muscular strength, agility, balance, endurance and motor coordination [7,9]. Because of diseases and aging, many older people perform only basic activities, being close to their maximum capacity. Both the elderly and HF patients present similar clinical status, exertion tolerance and limitations to their activity. Therefore, the Fullerton test may be useful in evaluation of young HF patients. It is cheaper, more feasible and easier for patients than a treadmill CPET, and it might be a valuable tool in an outpatient follow-up. However, its disadvantage is that it is a submaximal test for healthy individuals, and it requires investigation if the parameters measured with the Fullerton test can be used in evaluation of clinical state and prognosis of HF patients, and if these parameters correlate with the commonly used parameters of exertional gas exchange.

The aim of this paper was to determine if the Fullerton functional fitness test might be useful in evaluation of HF patients; particularly, the relationship between the parameters of exertional gas exchange and functional fitness in HF patients is investigated, and if HF patients performed worse in this test than patients without HF.

Methods

Twenty-one male patients, 40 years or older, were included in this prospective registry. They were hospitalized at the I Department of Cardiology of the University Hospital of Lord's Transfiguration of Poznań University of Medical Sciences due to ICD implantation or coronary angiography. Twelve of them had a stable chronic heart failure with reduced left ventricular ejection fraction (LVEF), defined as LVEF <40% as measured using echocardiography, the disease diagnosed more than three months prior to inclusion in this study, no history of intravenous diuretics administration during four weeks prior to inclusion to this study, New York Heart Association (NYHA) class I-III, and were treated according to the ESC guidelines. Three of them had ischemic cardiomyopathy and nine dilated cardiomyopathy. The rest of the patients formed a control group; all of them had arterial hypertension (AH) and four of them were diagnosed with stable coronary artery disease (CAD) without any evidence of HF. All the participants signed an informed consent form. This study was approved by the Ethical Committee of Poznań University of Medical Sciences and was conducted according to the Declaration of Helsinki. The data was processed and analyzed by authorized medical personnel only, and was anonymized and deidentified prior to analysis. The patients were examined by a physician, had laboratory tests performed, and underwent the Fullerton test.

The Fullerton test

The items included in the Fullerton test are "arm curl"- patient lifts a dumb-bell (2 kg for women, 3.5 kg for men), and the number of lifts in 30 seconds is counted (more is better); "30-sec chair stand" - patient sits down on a chair and stands up, and the number of repeated exercises in 30 seconds is counted (more is better); "back scratch" - patient tries to meet his/her hands at the back (one above the shoulder downwards, and the other upwards), and the distance between them is measured (smaller distance is better, may be negative if the patient reaches further); "chair sit-and-reach" - patient sits on a chair with one of his/her legs straight, and tries to reach his/her foot with the corresponding hand, and the distance between the foot and the hand is measured (smaller distance is better, may be negative if the patient reaches further); and "8-foot up-and-go" - patient sits in a chair, stands up, walks 8 feet (2.44 m), returns and sits down, and the time is measured (less is better); these exercises are followed with the six-minute-walk test (6 MWT). The first five items were performed as intended by the authors [7], but the 6 MWT was modified. To perform the 6MWT patients were asked to walk along a 20-meter corridor for six minutes; they were allowed to rest on the way as need be, and they wore a portable CPET device **(Figure 1)**. After six minutes the distance covered was measured (greater is better). All the tests were supervised, and the patients were informed how much time was left. Prior to evaluation, the patients were informed about the nature of this examination, and they underwent a short warm-up.

Gas exchange parameters

All the patients underwent a standard spirometry at rest. Exertional gas exchange parameters were recorded during 6MWT with a portable CPET device. The recorded parameters were the same as in a standard treadmill CPET; the most important being VO_2/kg [mL/min], VO_2 [L/min], VO_2 [as percentage of predicted] and VE/VCO_2 slope, which show the best prognostic value. All the parameters were recorded during the whole time of 6MWT, with particular interest in values at rest, anaerobic threshold (AT) and peak values. Also respiratory exchange ratio (RER) was measured to show whether the test is maximal or submaximal.

Statistical methods

Statistical analysis was performed using STATISTICA 10, Statsoft. Probability distribution of continuous variables was tested with Shapiro-Wilk test. T-student test was used to compare continuous variables with normal distribution, and Mann-Whitney U test

Figure 1 A patient during 6MWT with a portable CPET device.

was used for continuous variables with non-normal distribution. Pearson correlation was used to analyze correlations. The data is expressed as mean values with standard deviation for continuous variables and percentages for categorical variables. A p value of <0.05 was considered statistically significant for all the tests.

Results

General characteristics of both groups were compared **(Table 1)** to show a difference in the left ventricle ejection fraction that was significantly lower in HF patients. Moreover, the HF patients proved to be younger. Hemodynamic parameters **(Table 2)** showed that HF patients had a significantly higher heart rate at rest, and a significantly lower diastolic blood pressure after the exercise. There were no significant differences in spirometry parameters at rest and gas exchange parameters at AT. The HF patients showed a significantly higher VE/VCO_2 slope (34.1 SD 3.9 vs. 29 SD 4.3, p<0.005), and there was no significant difference as to peak VO_2/kg (mL/min), peak VO_2 (L/min) and peak VO_2 (as percentage of predicted). The HF patients had significantly worse results in all the items of the Fullerton test, apart from the "back scratch" exercise **(Table 3).**

Significant negative correlations were demonstrated between AT VE/VCO2, VE/VCO2 slope, 6 MWT distance and the results of Fullerton test **(Table 4).** Longer 6 MWT distance correlated negatively with both AT VE/VCO_2 and VE/VCO_2 slope. Similarly, better results in "arm curl" and "30-sec chair stand" were related to lower AT VE/VCO_2 and VE/VCO_2 slope. Better results of "chair sit-and-reach" correlated with lower peak VE/VCO_2 slope and of "8-foot up-and-go" with lower AT VE/VCO_2. There were no significant correlations between the "back scratch" and other investigated parameters. A correlation analysis was also performed between the results of 6 MWT, functional tests and peak VO_2 expressed as both the absolute values and the percentages of predicted limits. Higher peak VO_2 correlates with better results of 6 MWT, "arm curl" and "8-foot up-and-go". Higher peak VO_2 expressed as percentages of normal limits correlates with better results of 6MWT distance, "30-sec chair stand" and "arm curl".

Discussion

Our study provides a detailed analysis of physical fitness in the population of men with HF and a study of correlations between the CPET parameters taken during the 6 MWT and the Fullerton test. To our knowledge, this is the first analysis of physical fitness in correlation with exercise capacity measured as the 6 MWT distance and CPET parameters taken during the 6 MWT.

Main findings

- The patients with HF had worse fitness test results in comparison to the patients without HF, in spite of the older age of the latter.
- The patients with HF had shorter walking distance and worse CPET parameters in comparison to the patients without HF, especially those related to ventilatory efficiency.

Table 1 General characteristics of the HF patients and the control group.

	HF (n=12)	Control (n=9)	p
Age [years]	53.8 SD 12.7	60.4 SD 6.4	<0.001
Height [cm]	173.6 SD 9.4	172.7 SD 4.8	0.09
Weight [kg]	86.2 SD 12.5	88.1 SD 12.9	0.86
BMI [kg/m²]	28.7 SD 4.1	29.6 SD 3.1	0.92
LVEF [%]	29.2 SD 13.1	55 SD 5.6	0.039

BMI-body mass index; **LVEF**-left ventricle ejection fraction; **HF**-heart failure

Table 2 Hemodynamic parameters during 6MWT

	HF (n=12)	Control (n=9)	p
HR at rest (bpm)	81 SD 6.41	72.6 SD 10.27	0.014
HR at peak VO_2 (bpm)	97.3 SD 15.3	87.2 SD 12.2	0.07
DBP after (mm Hg)	76.7 SD 13.7	85.6 SD 10.1	0.025

HR-heart rate; **DBP**-diastolic blood pressure; **HF**-heart failure; **6 MTW**-six minute walk test.

Table 3 Fullerton test results in the investigated patients

	HF (n=12)	Control (n=9)	p
6MTW distance (m)	334.8 SD 95	508.4 SD 72.4	0.002
Chair stand (No. of repeated exercises in 30 s)	10.7 SD 1.6	15.1 SD 0.9	<0.001
Arm curl (No. of repeated exercises in 30 s)	13.0 SD 2.3	16.8 SD 1.2	<0.001
Chair sit-and-reach (cm)	-0.18 SD 2.3	1.81 SD 1.3	0.041
Back scratch (cm)	-0.91 SD 2.2	0.34 SD 1	0.16
8-foot up-and-go (s)	7.1 SD 2.2	5.6 SD 1.1	0.030

6 MTW-six minute walk test; **HF**-heart failure.

Table 4 Correlations between 6MWT and functional tests, and ventilatory parameters.

	AT VE/VCO_2		$VE/VCO_{2\ slope}$		peak VO_2/kg (mL/min)		peak VO_2 (% pred)	
	r	p	r	p	r	p	r	p
6 MTW	-0.58	0.006	-0.60	0.004	0.61	0.004	0.59	0.005
Chair stand	-0.57	0.007	-0.52	0.015	0.41	0.07	0.55	0.009
Arm curl	-0.62	0.003	-0.50	0.021	0.48	0.027	0.47	0.031
Chair sit-and-reach	-0.36	0.11	-0.49	0.023	0.14	0.56	0.15	0.53
Back scratch	-0.23	0.22	-0.22	0.34	0.21	0.35	0.27	0.24
8-foot up-and-go	0.59	0.006	0.59	0.36	-0.51	0.021	-0.43	0.06

6MTW-six minute walk test; **VE/VCO_2**-minute ventilation to CO_2 expiration; **AT**-anaerobic threshold; **VO_2/kg (mL/min)**-oxygen consumption per kg of body mass per min; **VO_2 (%pred)**-oxygen consumption as percentage of normal limit.

- There were significant correlations of the parameters of excessive exercise ventilation - VE/VCO_2, both at AT and VE/VCO_2 slope, with 6MWT distance, "chair stand", "arm curl" and "chair sit-and-reach" tests. There were also significant, but weaker than with VE/VCO_2, correlations of peak VO_2 with the 6MWT distance, "chair stand" and "arm curl".

Significance of the Fullerton test

Literature on this subject is scarce. Many authors investigate quality of life of HF patients, emphasizing the role of social support and reduction in number of rehospitalizations in a successful rehabilitation. These studies concentrate on older adults with HF [1,2,3,10]. However, it is observed in clinical practice that even young HF patients might not be able to perform normal daily activities, not to mention a CPET using a treadmill or a cycloergometer, at least at the beginning of their treatment and rehabilitation. HF patients often lead sedentary life styles because of limitations caused by their disease, and it seems justified to suspect that they are especially at risk of impaired physical fitness and loss of independence [11,12].

The Fullerton functional fitness test is commonly used to assess physical fitness in older adults, because it has been shown that healthy older adults perform worse in tests of aerobic endurance, maximal strength and muscular endurance in comparison to younger subjects [6,7,9,13]. According to the muscular hypothesis, impairment of musculoskeletal structure and function secondary to HF leads to development of exercise intolerance e.g. dyspnea or fatigue [14]. The so-far conducted studies show clearly that cardiac diseases, including HF, significantly impair physical fitness and life quality, however some authors show that problems with motor coordination in HF patients may be attributed to side effects of cardiac drugs [15].

It is recommended to evaluate exercise tolerance in patients with HF using 6 MWT or CPET [16], which however do not assess all the mobility capacities, like e.g. balance, flexibility, agility, and endurance. The Fullerton test may play a complimentary role in a holistic evaluation of HF patients. Węgrzynowska-Teodorczyk et al. have found that men with HF NYHA I-II had worse fitness test results in comparison to a control group of healthy males [17]. They found also that the most important determinants of physical fitness in men with HF were age and NYHA class [18].

Role of the Fullerton test items in evaluation of HF patients

Among the items of the Fullerton test the "arm curl" indirectly assesses upper body strength, and the predominantly engaged muscles are elbow flexors; the "chair stand" assesses lower body strength (especially work of quadriceps femur) [9,19]; the "back scratch" measures the upper body flexibility, and the "chair sit and reach" - lower body flexibility, and it determines primarily the elasticity of popliteal tendons [9]; the "8-foot up-and-go" test is an indirect measure of motor coordination and dynamic balance [19].

The hereby-presented study shows that the HF patients perform significantly worse in all the Fullerton test items, with the exception of the "back scratch" exercise, in spite of their younger age in comparison to the non-HF patients. The most important differences between the groups with HF and without HF were the results of 6 MWT distance and "chair stand", which suggests decreased endurance of the lower body musculature in patients with HF. The "arm curl" that assesses upper body strength was significantly decreased in patients with HF. Presumably, in patients with HF, the motor skills of big muscles in both the upper and lower limbs are significantly worse than in the control group. This shows the risk of cardiac cachexia and poor every-day activity in this group of patients. It is emphasized that heart failure is a generalized process affecting the whole organism including the body musculature.

There was only a trend towards worse peak VO_2 during 6 MWT in HF patients; however, 6 MWT is a submaximal test in patients with a non-advanced HF or without HF, and this was the case here, i.e. respiratory exchange ratio (RER) at peak exercise was <1.0 in both groups. The CPET parameters of increasing importance in evaluation of HF patients are VE/VCO_2 or VE/VCO_2 slope, which represent ventilatory efficiency. Recently it was recommended to assess VE/VCO_2 slope in all patients undergoing a CPET [20]. Both VE/VCO_2 and VE/VCO_2 slope are strong independent prognostic markers, even stronger than peak VO_2, also in a submaximal test [20]. In the hereby-presented study, VE/VCO_2 slope is significantly higher in the patients with HF compared to the non-HF. This study shows a correlation of AT VE/VCO_2, VE/VCO_2 slope, peak VO_2/kg, and VO_2 expressed as percentage of predicted value with the results of Fullerton test. A negative correlation of 6 MWT, „chair stand" and „arm curl" with AT VE/VCO_2 and peak VE/VCO_2 and a positive correlation of ''8-foot up-and-go" with AT VE/VCO_2 and peak VE/VCO_2 show a relationship between the respiratory parameters and physical fitness measured with the Fullerton test. These results suggest a need for further studies to show the place of the Fullerton test in evaluation of HF patients. The best item was the "arm curl" that significantly correlated with all the CPET parametrs. This analysis shows that decreased physical fitness is related to excessive respiratory response in the investigated patients.

Place of the Fullerton test in evaluation of HF patients

The investigated patients had no difficulties with performing all the six items included in the Fullerton test. Due to simplicity and safety of this test, it is suitable for evaluation of physical activity even in older or severely ill patients. The results of the hereby-presented study show that physical fitness correlates with exercise capacity, and that it is better in patients with longer 6 MWT distance or higher peak VO_2. It was also shown that physical fitness is influenced by ventilatory efficiency, probably even more than by exercise tolerance.

It is well known that pharmacotherapy of HF or exercise training improve exercise capacity and influence favorably ventilatory efficiency [21]. It is not known if these measures influence also physical fitness. We have found one paper reporting that an inclusion of walking training, and especially Nordic Walking, into a standard cardiac rehabilitation program for patients with CAD and preserved LVEF has a favorable effect on patients' physical fitness as measured using the Fullerton test [19]. There is a need for further studies to show the place of the Fullerton test in evaluation of HF patients, and if it can be used instead of CPET, which is not routinely available in e.g. outpatient follow-up. The Fullerton test is a versatile and easy tool, which makes it useful in both diagnostics and planning of rehabilitation of cardiac patients.

Study limitations

This is a pilot study and the investigated group counted only 22 male patients, in that 12 with HF, therefore the study does not reflect characteristics of the whole population of patients with HF.

Conclusion

- The patients with HF had worse fitness test results in comparison to the patients without HF.
- The patients with HF had worse results of walking distance and CPET parameters in comparison to the patients without HF, and especially those related to ventilatory efficiency.
- Lower physical fitness is related to lower exercise capacity and worse ventilatory efficiency.
- The Fullerton test, developed for older patients, may be useful in a complex evaluation of HF patients.

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