

Cardiopulmonary exercise testing for personalized job reintegration after acute cardiovascular attacks: a pilot cross-sectional study

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SUMMARY

Background: Cardiovascular diseases (CVD), particularly the ischemic heart disease, are a growing public health issue. In addition, the return to work after an acute cardiovascular attack represents a complex challenge. **Objectives:** To evaluate utility and safety of cardiopulmonary exercise testing (CPET), particularly performed “on site”, to promote a return to work in line with the residual working capacity. **Methods:** Fifty-nine workers affected by a major cardiovascular event, aged 18–63 years, have been enrolled between 2015 and 2018. All the patients underwent a CPET in outpatient clinic. Eleven workers also underwent the “on site” CPET, recorded during their working activities. **Results:** Outpatient clinic CPET outcomes (i.e. normal, mild impairment or moderate/severe impairment of cardiopulmonary function) were associated with the subjective perception of workers’ health status after returning to work. The “on site” CPET was found to be safe and reliable to promote a personalized return to work of patients. In 7 out of 11 patients, the values of O₂ consumption (VO₂) during the working activity were higher than 40% of VO₂ max as obtained from laboratory CPET. **Conclusions:** This study provides evidence for safety and usefulness of “on site” CPET for a personalized statement of fitness for work. This may facilitate the job retention of patients characterized by a high risk of unnecessary job loss. The use of CPET represents a first step of energy expenditure evaluation associated with specific working tasks.

RIASSUNTO

«Test cardiopolmonare per un reintegro lavorativo personalizzato dopo eventi cardiovascolari acuti» **Introduzione:** Le patologie cardiovascolari, in particolare la cardiopatia ischemica, costituiscono un problema prioritario di salute e la ripresa del lavoro dopo gli eventi cardiovascolari rappresenta un problema complesso. **Obiettivi:** Valutare il ruolo del test cardiopolmonare (CPET) eseguito in ambulatorio e la sicurezza e la possibilità di utilizzare il test cardiopolmonare condotto sul luogo di lavoro (CPET “on site”) nel reintegro lavorativo del paziente/lavoratore affetto da patologia cardiovascolare. **Metodi:** Sono stati arruolati 59 lavoratori nel periodo 2015–2018, di età compresa tra 18 e 63 anni, con diagnosi di evento cardiovascolare maggiore se sottoposti a CPET in ambulatorio. Per 11 dei lavoratori

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arruolati è stato eseguito anche CPET "on site". **Risultati:** Gli esiti del CPET eseguito in ambulatorio (in termini di categorie di compromissione della capacità funzionale, ovvero capacità funzionale conservata, lievemente ridotta, moderatamente/severamente ridotta) sono risultati associati con lo stato di salute percepito successivamente alla reintroduzione sul posto di lavoro. Il CPET "on site" si è rivelato sicuro ed utilizzabile ai fini di un reinserimento lavorativo più mirato, evidenziando consumi di ossigeno superiori al 40% del VO_2 max condotto in laboratorio in 7 pazienti su 11. **Conclusioni:** Il progetto ha dimostrato l'utilità del CPET sia ambulatoriale che "on site" ai fini di un reintegro lavorativo più mirato consentendo l'individuazione di limitazioni/prescrizioni più dettagliate per compito lavorativo oltre che per mansione, a maggior tutela della salute del lavoratore, ma al contempo a garanzia della conservazione del posto di lavoro; inoltre ha consentito di dare inizio alla mappatura del dispendio energetico di alcune mansioni in comparti lavorativi molto rappresentati nel territorio di Parma.

INTRODUCTION

Cardiovascular diseases represent the main cause of death and disability in western countries (8), causing approximately 3.9 million deaths per year and being responsible for 45% of disease-related deaths in Europe. Forty-five % of coronary events occur in patients of working age, which leads to an estimated annual loss of productivity of around 2 billion euros (13). Added to the progressive increase in retirement age, this suggests that reintegration at work after an acute cardiovascular event is a problem of great impact both in social and economic terms. A Register recently published by Smedegaard et al. out of 40,000 Danes shows that up to 25% of patients had not been permanently reintegrated at work after one year from the acute cardiovascular event (17). For Italy, available data derive from a single study conducted on 102 patients, showing that only 40% of patients had returned to work 60 days after the acute cardiovascular event (18).

After acute myocardial infarction (AMI), work reintegration represents a delicate issue, because the acute event can affect the patient's working capacity, reducing her/his tolerance to exertion, and causing increased susceptibility to physical, chemical, biological agents or complex organizational conditions, with consequences on the safety of the worker her/himself or of third parties. Some studies suggest that patients who return to work after AMI have a better quality of life and lower prevalence of anxiety and depression as compared to those who abstain from working activities (3, 5, 15), whereas little evidence has been produced of major relevant outcomes, such

as mortality and recurrence of major cardiovascular events. These studies also highlight "the need for interventions to address this patient-centered problem and its impact on health" (5, 10).

The main negative predictive factors of return to work highlighted in the literature are (3, 5, 12, 14, 17): (i) manual work / high energy consumption (> 3 METs); (ii) female gender; (iii) old age; (iv) reduced functional residual capacity; (v) low education level; (vi) residual heart failure; (vii) reduced ejection fraction; (viii) coexistence of peripheral or cerebrovascular arterial disease; (ix) psychosocial factors, such as anxiety and depression.

To date, neither occupational medicine nor cardiology scientific societies have published guidelines on the reintegration at work of the heart patient; the European guidelines on AMI (11) state that "the return to work after AMI represents an important indicator of recovery" and that "decisions should be individualized, based on the function of the left ventricle and the characteristics of the job". These indications are certainly correct, but they also are generic and difficult to interpret.

A useful tool to provide a more precise estimate of the residual functional capacity after an acute cardiovascular event is represented by the cardiopulmonary test (Cardio Pulmonary Exercise Testing, CPET) (16); this test, performed on an outpatient basis through the use of an exercise bike with an incremental ramp effort protocol and associated with the simultaneous quantification of respiratory parameters, allows the integrated analysis of cardiovascular, respiratory and metabolic responses to exercise (2) in order to measure the overall functional capac-

ity expressed in METs (Metabolic Equivalents) or in terms of oxygen consumption at the peak of the exercise (VO_2 max, expressed in ml/kg/min). Through these measures, the examination allows to evaluate the patient's cardiorespiratory functional capacity and provides an integrated analysis of the cardiovascular, ventilatory and metabolic responses to effort, allowing the determination of any limiting factors at different levels of exercise. Today, the test can also be carried out using portable equipment that can be used in settings other than the laboratory or outpatient clinics. Up to now, this use has mainly been limited to the evaluation of cardiopulmonary function in sports, e.g., while running or swimming (6,7).

To date, the patient in working age who has had an acute cardiovascular event often receives by the occupational health physician a statement of fitness for work that is excessively precautionary, without any effective quantification of his residual functional capacity. In some cases, this attitude can lead to an unnecessary loss of job. In fact, in the absence of an adequate clinical / functional assessment, the occupational health physician has only a few indications from available literature (9, 19) suggesting that tasks with a consumption of O_2 equal to 35-40% of the maximum aerobic capacity as assessed with stress tests are to be considered compatible with the post-AMI activity for a 6-8 h shift. These principles assume reference to tables already published and indicative of energy expenditure by type of activity

exemplified in Table 1 (1, 9, 19).

The present study was aimed at evaluating the usefulness of CPET for reintegration into work of patient suffering from cardiovascular diseases. In particular, the association between the patient's overall cardiorespiratory capacity was assessed in response to both standardized exercise and job performance after reintegration. In addition, the role of the cardiopulmonary test performed during work activity ("on site" CPET) was assessed for the quantification of energy expenditure associated with the execution of some tasks specifically related to his/her job at the time of patient's resumption of work after an AMI event.

METHODS

Subjects

In the period between January 2015 and October 2018, 59 workers were enrolled in the project "Promote and encourage the reintegration into work of the heart patient" designed as an observational cross-sectional investigation based on anonymized data from routine health surveillance procedures, which were in accordance with the Helsinki Declaration as revised in 2008. The privacy of participants was protected and participation was voluntary. Recruitment criteria included: (i) age between 18 and 63 years, (ii) diagnosis of acute coronary syndrome

Table 1: Job activities and oxygen consumption as expressed in METs (kcal/kg/h) (1, 9, 19)

Activity categories	METs	Job description, examples
Very light effort	<3	Sitting tasks (e.g., office work, chemistry lab work, computer work, light assembly repair, watch repair, reading, desk work), custodial work; activities requiring light effort (e.g., cleaning sink and toilet, dusting, vacuuming, light cleaning); driving a delivery truck, taxi, shuttle bus, school bus; sitting tasks requiring moderate effort (e.g., pushing heavy levers, riding mower/forklift, crane operation).
Light effort	3-5	Locksmith; carpentry general, activities requiring light to moderate effort (e.g., machining, working sheet metal, machine fitting, welding); auto repair; painting house furniture.
Moderate effort	5-7	Manual or unskilled labor: building road, driving heavy machinery, using heavy power tools such as pneumatic tools (e.g., jackhammers, drills), operating punch press, carrying objects about 50 to 74 pounds.
Vigorous effort	7-9	Using heavy tools (not power) such as shovel, pick, tunnel bar, spade; carrying objects weighing about 100 pounds or over; carrying heavy loads (e.g., bricks, tools); shoveling, more than 16 pounds/min; deep digging.
Very vigorous effort	>9	Forestry: ax chopping, very fast 1.25 kg axe, 51 blows/min, trimming trees, carrying logs.

(STEMI ACS; NSTEMI ACS ; UA ACS) or heart valve disease subjected to replacement surgery in the previous 60 days, (iii) forecast of the possibility of resumption of work in the 12 months following the event considered, (iv) demand by the work activity ≥ 3 METs. Exclusion criteria included: (i) clinical instability of the patient or need for further invasive procedures in the following 12 months (patients with incomplete therapeutic procedure, completion of subsequent revascularization intervention, patients awaiting further evaluation for implantation of devices or other major procedures), (ii) life expectancy of less than 12 months, (iii) inability or impossibility to complete all phases of the study.

Study protocol

For each enrolled patient, the following data were collected: (i) biometric data (weight, height), (ii) clinical diagnosis, (iii) cardiovascular risk factors, (iv) ejection fraction at the time of hospital discharge, (v) exposure to work-related risk factors impacting on the cardiovascular system.

Methods

The CPET was performed according to criteria indicated by the American Heart Association (2). The patients underwent cardiopulmonary testing on an outpatient basis, they had to estimate the effort on the 0-10 Borg Scale, and their functional capacity was assessed in terms of maximum consumption of O₂ both as VO₂ max (ml/kg/min) and as a percentage of the theoretical maximum expected value of VO₂ (VO₂%). The COSMED Quark CPET device (Rome, ITA) was used for the test.

Subsequently, the patients underwent a specialist evaluation by the occupational health physician, who collected the work history, made a general objective examination, and a psychological interview to complete the general framework. Information from the occupational health physician about the specific risk factors and the outcome of instrumental examinations were discussed in order to express a joint first opinion shared with the cardiologist regarding the reintegration into work, then used by the company's occupational health physician for the

judgment of the worker's fitness for work. In addition, 11 patients also underwent an "on site" cardiopulmonary test ("on site" CPET), which consisted of oxygen consumption recording for about 60 minutes, during the performance of various tasks characterizing the specific job. Such a registration was carried out under the supervision of both the cardiologist and the occupational health physician. The maximum VO₂ values (ml/kg/min), the average VO₂ (ml/kg/min) values and maximum R (or anaerobic threshold) reached during work activity were obtained from the registration made during the work shift. The Oxycon Mobile device (Care Fusion, Yorba Linda, CA) was used. Functional capacity and energy expenditure during job activities were evaluated by both the occupational health physician and the cardiologist for the purpose of resuming work.

After 2 years (range: 1-3 years after the acute cardiovascular event) on average, all the subjects who participated in the project were subsequently contacted for a telephone interview. All patients completed a questionnaire for the collection of the following data: (i) employment status at the time of the interview (employment, unemployment, retirement); (ii) number of days of absence due to illness over the 8-12 months following reintegration to work; (iii) subjective assessment of one's state of health on a scale from 0 to 10 (values ≤ 5 : unsatisfactory; 6-7: sufficient moderate; ≥ 8 : optimal).

Statistical analysis

Data were analyzed using the software SPSS version 25 for Windows: statistical analysis was based on non-parametric tests: either the Chi-square test or Fisher exact test for frequency comparisons, Spearman rank test and the Kendall's tau test to assess the correlation between variables and between results obtained relying on different methods, respectively.

RESULTS

Fifty-nine workers participated in the project, of which 48 were men (81.5%) and 11 women (18.5%), with a median age of 52 years [range 32-62 years]. Population characteristics, cardiovascular risk

factors, clinical diagnosis and occupational risk factors are shown in Table 2.

Among the working risk factors, 25% of the subjects (No. = 15) were exposed to both manual handling of loads and biomechanical overload of the upper limbs; 29% (No. = 17) in addition to manual handling of loads and biomechanical overload of the upper limbs, were also exposed to microclimatic risk factors and carried out tasks at an height of over two meters; 8.5% (No. = 5) were employed in jobs entailing night shifts, and according to Italian law were falling within the definition of “night workers”; 37% (No. = 22) had no specific cardiovascular work risk factor. In addition, 20% (No. = 12) had been classified as exposed to work stress as belonging to the categories for work-related stress as also highlighted by the CCM 2015 Project (4): banks, large-scale retail distribution, hotel / restaurant / cafe / catering (HORECA), social health sector, police and surveillance, transport / logistics, telecommunications, education.

All 59 patients underwent CPET in the out-patient clinic; in 28 patients (47.5%), this examination showed respectively a functional capacity maintained, in 26 (44.1%) a slight to moderate reduction and in 5 patients (8.5%) a moderate to severe reduction (Figure 1).

One year after the acute cardiovascular event, 56 patients or 95% of the total, returned to work. For 21 workers, a judgment of fitness for work was expressed without limitations or prescriptions, for 34 workers a reduction in working hours was requested, with possible exclusion from the night shift and/or from demanding transfers, and with limitations in relation to manual handling of generic loads or limitations on physical exertion; in 1 case a job change was necessary. Of the 5 patients for whom the CPET had shown a moderate to severe impairment of functional capacity (i.e., VO_2 peak < 16 ml/kg/min), thus characterized by a high “theoretical” risk of being unable to resume their job, 4 (80%) actually were able to do it.

Table 2 - Clinical and working features of study population

Variable	Study subjects No. = 59
Age (years, range)	52 (32-62)
Gender (M,%)	48 (81.5%)
Arterial hypertension (No., %)	21 (42%)
Diabetes (No., %)	18 (30%)
Smokers ¹ (No., %)	37 (59%)
Ex-smokers (No., %)	10 (17%)
Familiarity for cardiovascular diseases (No., %)	6 (10%)
Dyslipidemia ² (No., %)	31 (52%)
BMI \pm DS (kg/m ²)	27 \pm 2.4
Diagnosis at discharge:	
STEMI ACS	43 (73%)
NSTEMI ACS	9 (15%)
Other	7 (12%)
Ejection Fraction (mean % \pm SD)	50 \pm 6
Occupational risk factors for the CV system	
Manual handling of loads and/or biomechanical overload	15 (25%)
Manual handling of loads, microclimate, work at >2 m	17 (29%)
Night shift work	5 (8.5%)
None	22 (37%)

¹smoker is every patient smoking at the time of the event, regardless of the number of cigarettes or packs/year

²hyperlipidemic is every patient with LDL blood values > 100 mg/dl

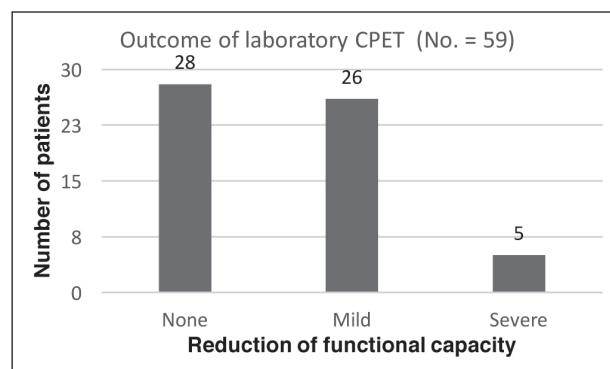


Figure 1 - The bar-graphs show the number of subjects grouped according to their cardio-respiratory function, (preserved, mildly reduced, severely impaired) as measured by CPET performed in outpatient clinic.

Results of the telephone interview (follow-up)

Of the 59 patients contacted by phone, 43 (73%) agreed to participate in the survey based on a standardized questionnaire, and were thus recruited for the second phase of the study. The questionnaire showed that the perception of the state of health was proportional to the degree of impairment of the functional capacity, the patients with major impairment showing a worse perceived status of health as compared to those with no or mild/moderate impairment (8.5 vs 8.0 vs 7.0, $p = 0.0294$) (Figure 2).

It has been hypothesized that the different level of severity, estimated by means of the CPET in the clinic, is indicative of the absenteeism in the 8 months following the reintegration into work (0 = no absence, 1 = absences for a total number less than or equal to 60 days, 2 = absences for a total number greater than 60 days). Cardiorespiratory function assessed by CPET in the outpatient clinic was not associated with absences cumulated over the 8 months following reintegration at work (Fisher exact test $p = 0.346$).

“On site” CPET

“On site” CPET registration was well tolerated, and the mask did not hamper the work activity even during tasks characterized by intense or precision manual work (e.g., welding). Table 3 shows data concerning the average VO_2 and their conversion into METs obtained during the performance of some

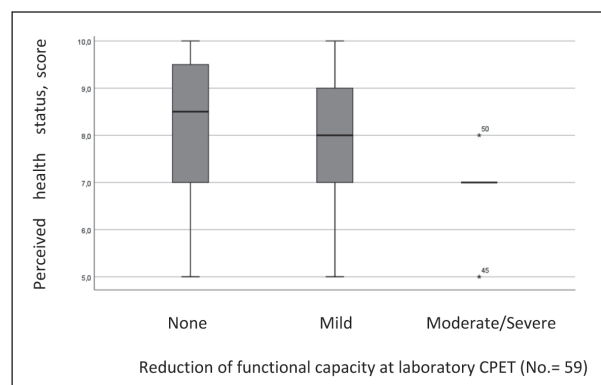


Figure 2 - Correlation between outcomes of laboratory testing CPET (expressed as reduction of oxygen consumption according to Weber classification (20): None: > 20 ml/kg/min peak VO_2 ; Mild: 16-20 ml/kg/min peak VO_2 ; Moderate/Severe: from < 16 ml/kg/min to < 10 ml/kg/min peak VO_2) and perceived health status after return to work (score ranging from 1 to 10).

tasks specific for the job. For 4 patients, the data showed an average consumption of O_2 during the activity of less than 40% of the functional capacity (VO_2 max obtained by laboratory CPET), while for 7 patients the mean VO_2 values were higher (Figure 3). In 72% of patients, the energy expenditure expressed in METs on the basis of the measurements carried out during the working activity was found to be different from that estimated on the basis of reference tables found in the scientific literature.

All patients undergoing “on site” CPET answered the telephone interview. The oxygen consumption during work categorized as greater or less than 40% of the VO_2 max obtained with CPET at the outpatient clinic did not show any correlations with either the perceived health status or the number of absences due to illness ($p = 0.927$ and $p = 0.364$, respectively).

After one year, all patients who underwent the cardiopulmonary test in the workplace carried out regular work; specific limitations or requirements had been imposed in relation to keep the demand associated with individual tasks within both the scope of the task and acceptable oxygen consumption.

DISCUSSION

Our study shows that in a population at high risk of non-reintegration (medium-high consump-

Table 3: VO₂ (mean) and corresponding METs (metabolic equivalents) values as obtained during “on-site” CPET among 11 workers reintegrated in their own job after the acute CVD

Job	“on site” CPET	
	Mean VO ₂ (ml/kg/min)	METs
Office cleaner	8.75	2.5
Metalworker tester	9.74	2.8
Assembler or layer of power lines	17.00	4.8
Electrician (industry electrical systems)	13.00	3.7
Packaging (personal hygiene products)	14.00	4.0
Ham factory worker	11.80	3.4
Canteen attendant	10.32	2.9
Tinsmith construction worker and roofing assembler	11.45	3.3
Welder and carpenter	6.80	1.9
Metalworker in charge of the presses	9.11	2.6

tion jobs, relatively advanced age, reduced FE), the use of CPET in the outpatient clinic was useful for quantifying the functional capacity of the patient and this had a positive impact possibly accounting for the high percentage of subjects returning to work after the acute cardiovascular event. In the present study, 95% of patients resumed their job compared to the average reported by the literature not exceeding 75% (17). In fact, the measurement of the cardiorespiratory functional capacity of the patient-worker can allow the occupational health physician and the cardiologist to analyze the patient’s actual energy expenditure, avoiding too precautionary judgments and ruling out residual doubts about the safety of reintegration. It also showed that the degree of impairment of the overall functional capacity was correlated with the perceived health score ($p = 0.0294$). The same cannot be said for absenteeism, expressed in terms of absences during the 8 months following the reintegration into work ($p = 0.346$).

Our study also made it possible to test, for the first time in occupational settings, a methodology mainly used for sports activities, by using the instrumentation for carrying out the cardiopulmonary test in the workplace (“on site” CPET). The main results showed that (i) the “on site” CPET can be used without contraindications or limitations during work activity without the need to stop recording or change the work routine due to the device; (ii) the use of the “on site” CPET during work is a useful

tool to quantify the actual energy expenditure of the individual worker, particularly important for activities with a high physical demand; (iii) the energy expenditure of the patients covered by this study was different from reference values reported in tables built for the healthy population, in relation to the presence of a reduced cardiorespiratory functional capacity of the patient; (iv) the use of the “on site” CPET seems to be associated with a high percentage of subjects reintegrated at work, probably due to the possibility of providing more precise limitations and / or prescriptions avoiding undue and excessive cautions not justified by the actual functional picture of the patient with respect to the job demand. In choosing the eligibility criteria, in fact, thanks to the measurement in the field for each worker of the value of “average VO₂ obtained during the CPET on site” and thanks to its comparison with the value of “VO₂ max obtained in the laboratory” (expressed as the ratio “Average VO₂ obtained during the on-site CPET / VO₂ max obtained in the laboratory”), it is possible to apply, at least partially, what is indicated in the literature (9, 19). The work activity is considered “optimal” or adequately tolerated from the point of view of physical load if it requires an average oxygen consumption equal to 35-40% of the VO₂ max obtained during CPET in the outpatient clinic for a continuous period of 6-8 hours and does not imply peak VO₂ values higher than 2/3 of the VO₂ max obtained during CPET.

Limitations of the study

The present study has important limitations: (i) the small number of subjects studied did not allow stratification for both clinical characteristics and job. For this reason, it is necessary to increase the number of subjects studied to consolidate the results based on these preliminary data; (ii) a selection bias cannot be rule out, especially with respect to the follow-up data, owing to the loss of patients who didn't agree to answer the telephone interview; (iii) the descriptive nature of study, in which each patient was control of himself. Indeed, it is difficult to standardize, if not in a very rough way, the energy expenditure of the individual work activity, as each subject, based on anthropometric data and functional capacity, can respond differently to the workload associated with similar activities in terms of energy expenditure for the standard healthy worker. From this point of view, we believe that the concept of precision medicine can be applicable also in this field.

The cardiopulmonary test conducted in the workplace ("on site") was well tolerated. For this reason, we believe that it can also be used to create a mapping relating to energy expenditure, expressed in METs, characterizing on average the tasks most represented in our region. In order to proceed with the validation and drafting indicative tables of energy expenditure per job, it is necessary to continue the collection of data by increasing the number of subjects studied and recruiting healthy workers.

In conclusion, our study highlights how the use of the cardiopulmonary test performed not only in outpatient clinic under standard conditions, but also "on site" during usual work activities, can be a suitable strategy for optimizing the assessment of patients' residual working capacity in the phase resumption of work with significant physical load after a major cardiovascular event.

NO POTENTIAL CONFLICT OF INTEREST RELEVANT TO THIS ARTICLE WAS REPORTED BY THE AUTHORS.

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