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ORIGINAL REPORT

RELATIONSHIPS AMONG MEASURES OF PHYSICAL FITNESS IN ADULT PATIENTS WITH HEART FAILURE

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Objectives: **To describe the relationships among 3 measures of physical fitness (exercise capacity, muscle function and functional capacity) in patients with heart failure, and to determine whether these measures are influenced by impairment of movement.**

Methods: **Secondary analysis of baseline data from the Italian subsample (*n* = 96) of patients with heart failure enrolled in a randomized controlled trial, the HF-Wii study. Exercise capacity was measured with the 6-min walk test, muscle function was measured with the unilateral isotonic heel-lift, bilateral isometric shoulder abduction and unilateral isotonic shoulder flexion, and functional capacity was measured with the Duke Activity Status Index. Principal component analysis was used to detect covariance of the data.**

Results: **Exercise capacity correlated with all of the tests related to muscle function (r = 0.691–0.423, *p* < 0.001) and functional capacity (r = 0.531). Moreover, functional capacity correlated with muscle function (r = 0.482–0.393). Principal component analysis revealed the bidimensional structure of these 3 measures, thus accounting for 58% of the total variance in the variables measured.**

Conclusion: **Despite the correlations among exercise capacity, muscle function and functional capacity, these measures loaded on 2 different factors. The use of a wider range of tests will help clinicians to perform a more tailored assessment of physical fitness, especially in those patients with heart failure who have impairment of movement.**

LAY ABSTRACT

Physical fitness is a complex concept, and is particularly affected in patients with heart failure, especially in those with impairment of movement. Physical fitness is often assessed by examining only some of the factors involved, mainly based on physical endurance or strength. This study explored the relationship among 3 different measures of physical fitness: exercise capacity, muscle function and functional capacity. Moreover, the study showed how these 3 measures, despite their good correlation, can be used to assess 2 different factors related to physical fitness. These results should encourage clinicians to choose a tailored strategy to assess physical fitness in patients with heart failure, paying particular attention to patients with impairment of movement.

Key words: heart failure; physical fitness; exercise capacity; muscle function; functional capacity; movement impairment; rehabilitation.

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Reduced physical fitness is a common problem in patients with heart failure (HF) (1). Physical fitness is complex and includes several objective and subjective domains, of which the most important and the most evaluated are: exercise capacity, muscle function, and functional capacity (2). This multidimensionality in physical fitness should be explored using multiple methods, not with tests that evaluate only physical capacity. A proportion of patients with HF may be unable to perform or complete physical tests due to impairment of movement (3, 4), such as chronic shoulder or knee pain reducing their capacity for exercise (5).

Exercise capacity was defined as the maximum amount of physical exertion that a person can sustain (6). Lower exercise capacity (e.g. <300 meters in the 6-min walk test (6MWT)) is strongly associated with higher mortality due to HF (7). Higher exercise capacity allows patients with HF to be more active at a greater intensity or for a longer period and to perform activities of daily living better (8). A 5% improvement in exercise capacity is associated with a 10% reduction in cardiac re-hospitalization and all-cause mortality risk (9). In most cases, exercise capacity is measured with the 6MWT. However, this test only measures the distance (in m) walked in 6 min (10), and does not evaluate the exercise capacity of the upper limbs.

Muscle function is determined by a combination of muscle mass, muscle strength and muscle power (11). Muscle function is particularly affected in patients with HF, possibly because of a maladaptation in the skeletal muscle fibres (12). Muscle function in patients with HF is important in the rehabilitation setting because it allows for a more comprehensive exploration of physical fitness. This assessment is currently not performed with a single standard method, but through a variety of

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evaluations based on tests that involve different muscle groups (13–15). The muscle function test (MFT) enables assessment of the muscle endurance of both the lower and the upper limbs (12).

Finally, functional capacity was defined as patients' ability to perform activities of daily living at their own pace (16). Functional capacity is often measured subjectively with the Duke Activity Status Index (DASI), a self-administered questionnaire (17). The DASI enables brief assessment of the functional capacity of selected aspects of daily living that can influence quality of life in cardiovascular patients (18).

Since physical fitness is multidimensional, it is difficult to assess, especially in patients with HF (14, 19). Both objective (e.g. 6MWT) and subjective (e.g. DASI) methods can be used. This measurement can become even more challenging in patients with HF who have movement impairment, e.g. due to stroke or claudication. Although exercise capacity, muscle function and functional capacity may represent different, but related, aspects of the multidimensionality of physical fitness in patients with HF, few studies have analysed these relationships. In most instances, only 2 of these 3 aspects have been evaluated (14, 20). Borland et al. reported a moderate positive correlation between exercise capacity and muscle function (14), and Myers et al. reported a moderate positive correlation between exercise capacity and functional capacity (20); however, no evidence regarding the relationship between muscle function and functional capacity was described. Therefore, the aims of this study were 2-fold: first, to describe the relationships among 3 measures of physical fitness (exercise capacity, muscle function, and functional capacity) in patients with HF; and, secondly, to determine whether these measures are affected by impairment of movement.

The research questions addressed by this study were:

- Are there relationships among exercise capacity, muscle function, and functional capacity in patients with HF?
- Are there relationships among the 3 measures of physical fitness and demographic and clinical data, such as age, sex, New York Heart Association (NYHA) classification, and ejection fraction (EF)?
- Is there a relationship between physical fitness and movement impairment in patients with HF?

METHODS

Participants and setting

This study used the data collected for Italian patients who participated in the HF-Wii study (21), an international randomized controlled trial that aimed to improve exercise capacity in patients with HF through the use of exergaming (clinicaltrial.gov identifier: NCT01785121). Patients were enrolled in the Villa delle Querce Hospital in Nemi (Rome, Italy) from October 2014 to December 2016. The eligibility criteria were specified in the original study protocol (21). Briefly, the HF-Wii study enrolled adult patients with HF, who were able to use exergames (without limiting visual, hearing, motor or cognitive impairments) and with a life expectancy of more than 6 months (21). Regarding movement impairment, only those patients who were not able to swing their arms at least 10 times in a row were excluded. In addition to the data from the HF-Wii protocol, additional data on functional capacity were collected.

Ethical considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki (2008 version) and the Medical Research Involving Human Patients Act of Italy, the country involved in this multicentre study. Ethical approval (n. 101.14 prot. N. 47867 of 02.07.2014) was obtained in Italy. All of the patients were fully informed about the study goals. They were also reassured about the confidentiality of their data, and provided signed informed consent before the start of data collection.

Measures

A battery of measures was used in the HF-Wii study, but, for the purpose of this study, only the following have been included: exercise capacity, muscle function, functional capacity, and demographic and clinical data.

Exercise capacity

Exercise capacity was assessed with the 6MWT. The distance (m) walked in 6 min on a flat, firm surface on a linear track marked with visible signs represents the 6MWT score (10). It is a frequently used, reliable and well-validated measure of exercise capacity for patients with HF (22). The 6MWT has been also recommended for monitoring the course of the disease and the evaluation of the effects of interventions in these patients (23). Some studies have reported a correlation between the 6WMT and peak of oxygen consumption ($r=0.490–0.790$) (20, 24) and EF ($r=0.280$) (20). A distance ≥300 m walked during the 6MWT has been shown to have a prognostic value for patients with HF. Patients who walked ≥300 m had a lower event-free survival at 36 months than patients who walked less than 300 m (25). Considering its objectivity and lower cost, the 6MWT represents a valid method for assessing exercise capacity (3).

Muscle function test

The muscle function isotonic test (MFT), which simulates the muscle function normally required for activities of daily living, was used. The MFT is composed of 3 evaluations, which provide 3 different scores: the unilateral isotonic heel-lift, bilateral isometric shoulder abduction, and unilateral isotonic shoulder flexion (12). The MFT has also been used for patients with other cardiac diseases, such as coronary artery and congenital heart diseases (26, 27). Age and NYHA functional class are the main predictors of MFT scores in patients with congenital heart disease (27); however, no correlations have been found between MFT scores and EF in patients with HF (28).

The unilateral isotonic heel-lift was performed by having the patient touch the wall with the fingertips while their arms were elevated to shoulder height for balance. The patients had to perform a maximal heel-lift on a 10° tilted wedge: one lift every other second, timed by a metronome, in accordance with Gaffney et al. (29). The contralateral foot was held slightly above the floor, and the number of maximal heel rises completed for each leg was recorded.

The bilateral isometric shoulder abduction was performed by having the patient sit on a stool with his or her back touching the wall and a 1-kg dumbbell in each hand while both arms were elevated to 90°. This position was held as long as possible. The patient could be asked to correct the position once during the test, but the test was discontinued if this instruction need to be given a second time. The time (in s) for which the 90° angle of abduction was held was recorded.

The unilateral isotonic shoulder flexion was performed by having the patient sit on a stool with his or her back touching the wall and a weight (3 kg for males and 2 kg for females) held in the hand of the arm to be tested. The patient was asked to elevate the arm from a 0° to 90° flexion as many times as possible at a speed of 20 lifts per min timed by metronome. The patient could be asked to correct the flexion once; however, the test was discontinued on the second occurrence of an incorrect flexion. The number of flexions completed for each arm was recorded.

The test-retest reliability of MFT for all 3 evaluations have been shown to be very high (r_s=0.90–0.99) (12).

Functional capacity

The DASI was used to measure functional capacity. The DASI is a brief 12-item scale that determines functional capacity by assessing patients' ability to participate in a spectrum of daily activities (18). Patients report their ability to perform personal care, ambulation, housework, yard work, sexual relations, and recreational activities. The possible responses for each item are "yes" or "no", and each "yes"' corresponds to a weighted score in terms of the metabolic equivalent (MET) associated with the proposed activity. The total DASI score ranges between 0 and 58.2, with higher scores reflecting better functional capacity. DASI validity was shown with significant correlation with the peak oxygen consumption (r=0.580) (18), the N-terminal pro-brain natriuretic peptide levels (r=0.670) (17) and NYHA class (r=–0.653) (30). Moreover, the functional capacity assessed by the DASI has a strong prognostic value in risk stratification for long-term adverse clinical events and mortality at 5 years in cardiac patients (31, 32), and the measure is an independent predictor of both death and myocardial infarction (33). DASI reliability was shown to be adequate in several studies (Cronbach's alpha ranging from 0.86 to 0.93) and also in the present study (Cronbach's alpha=0.80). Before its use, the DASI underwent to translation and back-translation and cross-cultural adaptation according to international guidelines (34).

Sociodemographic data

The patients reported their age, sex, education, and marital status. Data on HF aetiology, heart rhythm, EF, and NYHA functional class collected from the patients' medical records. Regarding the inclusion and exclusion criteria, information on upper or lower limbs impairment was obtained by collecting information from patients' medical files (e.g. clinical history, reports), and by asking patients for confirmation before the exercise tests.

Statistical analysis

Statistical analysis was performed in 5 steps. First, descriptive analyses were used to describe the sociodemographic and clinical characteristics, as well as the physical fitness data, of the participants (6MWT, MFT and DASI scores). Normal distribution of the data was analysed by the Kolmogorov-Smirnov test and by visual inspection of quantile-quantile plot (q-q). Secondly, an exploratory factor analysis was performed to detect the dimensionality of DASI. Principal component analysis with promax rotation was used, considering factor loading >0.30, eigenvalue more than one and the scree plot of eigenvalues.

Thirdly, 1-way analysis of variance was used to assess differences in age, NYHA classification and EF in the patients who scored above or below the median of each physical fitness test. The Kolmogorov-Smirnov test was used to define the differences in sex distribution (male vs female) of the patients who scored above or below the median. Fourthly, to determine the relationships among the 6MWT, MFT and DASI scores, Spearman's ranked correlation coefficient was performed. Correlations among demographic and clinical variables, such as age, sex and NYHA class, were also assessed. The possible influence of movement impairment on physical fitness assessment was explored by using Spearman's rho to determine the relationships among the number of impaired limbs and the 6MWT, MFT and DASI scores. A Bonferroni correction on correlation was conducted to protect from Type I error. Interpretation of the size of the correlation was performed according to Hinkle et al. (35) as follows: 0.00–0.30 "little if any correlation", 0.30–0.50 "low correlation", 0.50–0.70 "moderate correlation", 0.70–0.90 "high correlation", and 0.90–1 "very high correlation". Fifthly, to detect the structure in the relationships among exercise capacity, muscle function (considering all 5 tests) and functional capacity, principal component analysis was conducted using a promax rotation. Principal component analysis was evaluated considering factor loading >0.30, eigenvalue more than 1 and scree plot of eigenvalues. All of the data were analysed using IBM SPSS Statistics for Windows version 22.0 (IBM Corp., Armonk, NY, USA). A *p*-value below 0.05 was considered statistically significant. Sample size was performed using G*Power 3.1.9.2. With an estimated medium effect size of 0.30, a power of 80% and α level of 5%, a sample of 84 participants was considered adequate. The adequacy of the correlation matrix for factor analysis was investigated with the Bartlett's test of sphericity (which should have a *p*-value <0.05) and the Kaiser-Meyer Olkin (KMO) test (which should have a value >0.70).

RESULTS

Sociodemographic and clinical characteristics of the sample

A total of 328 patients were screened, and, of these, 96 patients with HF agreed to participate in the study (mean age 72 standard deviation (SD) 10 years). The patients who declined to participate were older (76 vs 72 years; $p<0.001$) and in a higher NYHA class (χ^2=14.619; df=3; p=0.002) than those enrolled in the study. Most of the participants were men (73%), classified as NYHA II and NYHA III (97% in total), with a mean EF of 44% (SD 10) (Table I). Of the patients with HF participating in the study, 28% had reduced ability because of impairment of at least one limb, but all of them were able to swing their arms 10 times in a row. The prevalence of limb impairments were: shoulder pain (10%), knee pain (9%), and claudication (6%). Other characteristics of the sample are shown in Table I.

Exploratory factor analysis of DASI

The correlation matrix of the DASI items was suitable for factor analysis (Bartlett's test of sphericity = 257.884; df = 66; $p < 0.001$; KMO = 0.804), which resulted in the same factorial structure as was found in the original study (4); specifically, with the factors "mild activities" and "moderate to strenuous activities". These 2 factors explained 44% of the common variance.

Exercise capacity, muscle function and functional capacity

All of the patients walked approximately 222 m (SD 114.7 m) on the 6MWT. The median was 227 m (Table II). In total, 20 patients stopped before 6 min for various reasons, fatigue being the main cause (55%). Overall, 26 patients walked 300 m or more (27%), and 70 walked less than 300 m (73%). Of the patients who walked less than the median of 227 m, significantly more were female ($p = 0.002$), older (76 vs 67 years; df = 1; F = 23.788; $p < 0.001$) and in a higher NYHA class (2.75 vs 2.15; df = 1; F = 28.416; $p = 0.001$).

Because of physical impairment unrelated to HF, which affected movement of the arms or legs, all of the patients did not perform the complete MFT. Specifically, 28% of patients had impairment of movement, which affected their capacity to perform the MFT. The patients with HF who scored less than the median in each MFT evaluation were also significantly more often female, older and in a higher NYHA class. In particular, male patients reached significantly better performances in right heel-lift ($p = 0.002$), shoulder abduction ($p = 0.003$), right shoulder flexion ($p = 0.004$) and left shoulder flexion ($p = 0.035$). Older patients did not reach the cut-off fixed in right heel-lift (74 vs 69 years; df = 1; F = 6.007; $p = 0.016$), left heel-lift (74 vs 69 years; df = 1; F = 6.007; $p = 0.016$), and shoulder abduction (74 vs 69 years; df = 1; F = 4.763; $p = 0.032$). Finally, the cut-off fixed for MFT evaluation were not reached by patients with a higher NYHA class: right heel-lift (3 vs 2; df = 1; F = 29.611; $p < 0.001$), left heel-lift (3 vs 2; df = 1; F = 16.655; $p < 0.001$), shoulder abduction (3 vs 2; df = 1; F = 6.422; $p = 0.013$), right shoulder flexion (3 vs 2; df = 1; F = 7.483; $p = 0.007$), and left shoulder flexion (3 vs 2; df = 1; F = 8.969; $p = 0.004$).

The mean DASI score was 24.83 (SD 13.60) (Table II), and the median was 25. The patients with HF who scored less than the median were more often female ($p = 0.005$), older (75 vs 68; df = 1; F = 15.248; $p < 0.001$) and in a higher NYHA class (2.68 vs 2.20, df = 1; F = 16.072; $p < 0.001$).

In total, 29% of the patients scored below the median scores on all the tests; 27% scored above the median on all of the tests. The remaining 44% included patients who had higher then median scores in a maximum of 2 tests. The results with the most underlying discre-

Table I. Sociodemographic and clinical characteristics of the sample ($n = 96$)

Characteristics	
Age, years, mean (SD)	72 (10)
Male sex, *n* (%)	70 (73)
Education, *n* (%)	
Primary school	36 (37)
High school	36 (37)
University or college	23 (24)
Other	1 (1)
Marital status, *n* (%)	
Married/relationship	56 (58)
Single/divorced/widowed	37 (39)
Other	3 (3)
Smoking, *n* (%)	
Yes	20 (21)
Aetiology of heart failure, *n* (%)	
Ischaemia	19 (20)
Hypertension	55 (57)
Cardiomyopathy	61 (63)
Valvular heart disease	27 (28)
ECG rhythm, *n* (%)	
Sinus	64 (67)
Atrial fibrillation	19 (20)
Pacemaker	12 (12)
Unknown	1 (1)
Ejection fraction, mean (SD)	44 (10)
NYHA class, *n* (%)	
I	4 (4)
II	48 (50)
III	41 (43)
IV	3 (3)
Time from diagnosis, months, mean (SD)	52 (80)
Movement impairment (at least 1 limb impaired), *n* (%)	27 (28)
Right leg impairment	13 (13)
Left leg impairment	16 (17)
Right arm impairment	9 (9)
Left arm impairment	11 (11)

ECG: electrocardiogram; NYHA: New York Heart Association classification; SD: standard deviation.

Table II. Mean and median scores for exercise capacity, muscular function and functional capacity

Variables ($n = 96$)	Mean (SD)	Median (cut-offs)
6MWT, m	222.36 (114.26)	227
Muscle function test		
Right heel-lift, *n*	13.79 (8.34)	12
Left heel-lift, *n*	13.47 (7.63)	11
Shoulder abduction, s	63.61 (44.05)	55
Right shoulder flexion, *n*	14.29 (8.31)	12
Left shoulder flexion, *n*	14.13 (7.66)	11
DASI (score range 0–58.2)	24.83 (13.60)	25

6MWT: 6-min walk test; DASI: Duke Activity Status Index; SD: standard deviation.

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Table III. Correlation matrix ($n = 96$)

		Muscle function test									
	6MWT	RHL	LHL	SA	RSF	LSF	DASI	Age	Sex[a]	NYHA	EF
6MWT	1										
Muscle function tests											
RHL	0.691**	1									
LHL	0.608**	0.861**	1								
SA	0.511**	0.452**	0.383**	1							
RSF	0.423**	0.472**	0.386**	0.727**	1						
LSF	0.447**	0.525**	0.450**	0.634**	0.759**	1					
DASI	0.531**	0.465**	0.482**	0.448**	0.393**	0.395**	1				
Age	−0.335**	−0.311**	−0.212	−0.324	−0.235	−0.170	−0.325**	1			
Sex[a]	−0.407**	−0.367**	−0.249	−0.393**	−0.279**	−0.199	−0.392**	0.199	1		
NYHA	−0.540**	−0.539**	−0.470**	−0.244	−0.244	−0.293**	−0.482**	0.341**	0.238	1	
EF	−0.136	−0.046	−0.068	−0.084	0.034	−0.064	−0.110	0.005	0.166	−0.056	1

**$p < 0.001$.
[a]Variable dichotomized: 0 = male; 1 = female – point-biserial correlation was used.
Bonferroni correction: new p-value fixed at < 0.005.
6MWT: 6-min walk test; RHL: right heel-lift; LHL: left heel-lift; SA: shoulder abduction; RSF: right shoulder flexion; LSF: left shoulder flexion; DASI: Duke Activity Status Index; NYHA: New York Heart Association classification; EF: Ejection fraction.

pancies were the DASI scores. Twelve (12%) patients had a score above the median on the DASI, but not on the 6MWT or MFT. Similarly, 7 patients (8%) had scores above the median in both the 6MWT and the MFT, but not on the DASI.

Relationships among exercise capacity, muscle function, functional capacity and clinical variables

As shown in Table III, there were moderate positive correlations between 6MWT and each evaluation in the MFT. Moreover, the 6MWT was correlated with the DASI, age, sex and NYHA class (Table III).

Positive correlations were also found between each evaluation in the MFT and DASI scores. There was also a very high correlation between the contractions made by the right and the left arms and the right and the left legs in the 2 unilateral isometric MFT evaluations. The results of the MFT lower limb tests were significantly correlated with age, sex (right leg) and NYHA classification. The upper limb tests result correlated with sex (not with the LSF) and NYHA classification (only with LSF). The DASI score was correlated with age, sex and NYHA class (Table III). The correlations among the 6MWT, MFT and DASI scores are shown in 3-D scatter plots for each MFT evaluation (Figs 1–5). These Figs show that the patterns of correlations were similar, with no outliers. The only exceptions were the scores related to the movement-impaired patients with HF. EF was not significantly correlated with any of the physical fitness variables.

Regarding movement impairment, Table IV shows low-to-moderate correlation between impaired limbs and the respective physical fitness test, except for the DASI score.

To detect the structure in the relationships among exercise capacity, muscle function (considering all 5 tests) and functional capacity, a principal component

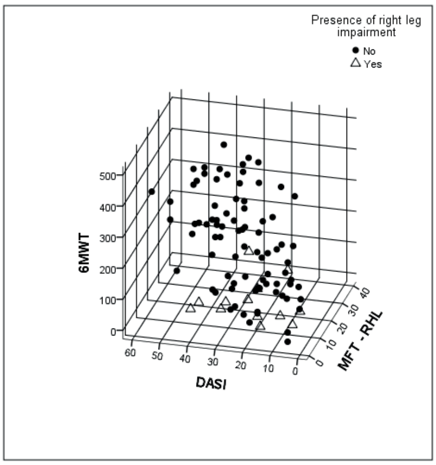

Fig. 1. 3-D scatter plot of correlations among 6-min walk test (6MWT), muscle function test (MFT) (right heel-lift) and Duke Activity Status Index (DASI), in the presence of right leg impairment.

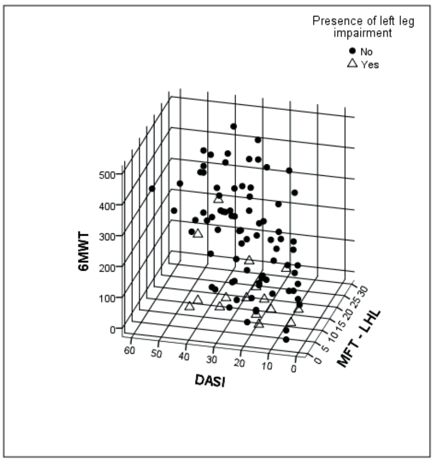

Fig. 2. 3-D scatter plot of correlations among 6-min walk test (6MWT), muscle function test (MFT) (left heel-lift) and Duke Activity Status Index (DASI), in the presence of left leg impairment.

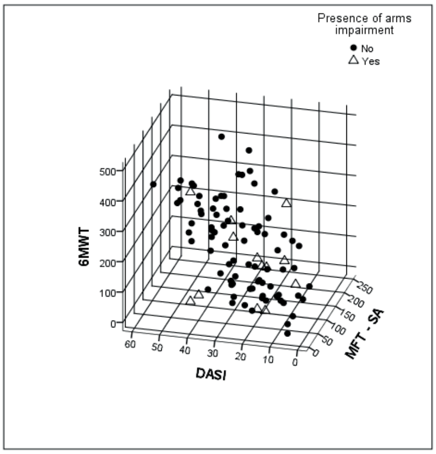

Fig. 3. 3-D scatter plot of correlations among 6-min walk test (6MWT), muscle function test (MFT) (shoulder abduction) and Duke Activity Status Index (DASI), in the presence of arm impairment.

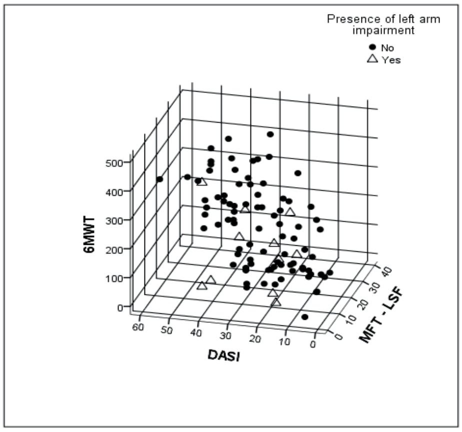

Fig. 5. 3-D scatter plot about correlations among 6-min walk test (6MWT), muscle function test (MFT) (left shoulder flexion) and Duke Activity Status Index (DASI), in the presence of left arm impairment.

analysis, which showed the presence of 2 different factors, was performed (Table V). The correlation matrix was suited for factor analysis (Bartlett's test of sphericity = 368.498; df = 21; $p < 0.001$; KMO = 0.776). As shown in Table V, factor I included the 6MWT, number of right heel-lifts, number of left heel-lifts, and DASI score. Factor II included resistance during shoulder abduction, the number of right shoulder flexions and left shoulder flexions. The 2 factors are referred to as "lower limbs capacity" and "upper limbs capacity", respectively. Together, these factors explained 58% of the total variance of the measured variables.

These results indicate that physical fitness, exercise capacity, muscle function and functional capacity assessment were clearly bi-dimensional, with a first factor that included only lower limbs capacity and a second factor that included only upper limbs capacity.

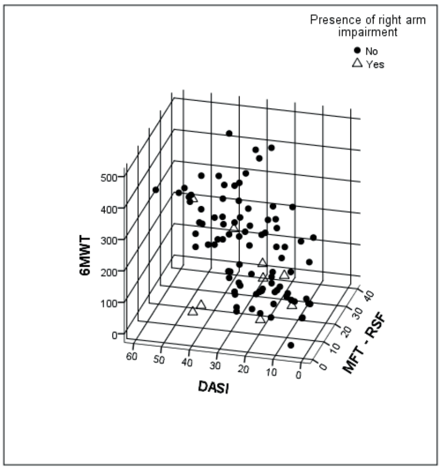

Fig. 4. 3-D scatter plot of correlations among 6-min walk test (6MWT), muscle function test (MFT) (right shoulder flexion) and Duke Activity Status Index (DASI), in the presence of right arm impairment.

Table V. Results of exploratory principal component analysis with promax rotation ($n = 96$)

	Components	
	1	2
6-min walk test	**0.594**	0.221
Right heel-lift	**0.929**	0.017
Left heel-lift	**0.995**	−0.136
Shoulder abduction	0.023	**0.802**
Right shoulder flexion	−0.074	**0.942**
Left shoulder flexion	0.120	0.737
Duke Activity Status Index	**0.416**	0.237
Variance explained, %	**54**	**14**

Factor loadings higher than 0.05 are shown in bold.

Table IV. Correlation matrix for limb impairment and exercise capacity, muscle function and functional capacity ($n = 96$)

		Muscle function test					
	6MWT	RHL	LHL	SA	RSF	LSF	DASI
Right leg impaired[a]	−0.360**	−0.541**	−0.452**	−0.246	−0.220	−0.225	−0.208
Left leg impaired[a]	−0.308**	−0.446**	−0.541**	−0.146	−0.124	−0.147	−0.161
Right arm impaired[a]	−0.058	−0.055	−0.010	−0.415**	−0.498**	−0.368**	−0.072
Left arm impaired[a]	−0.032	−0.111	−0.083	−0.370**	−0.376**	−0.548**	−0.081

**$p < 0.001$.
[a]Variable dichotomized: 0 = no impairment; 1 = impairment.
Bonferroni correction: new p-value fixed at < 0.007.
6MWT: 6-min walk test; RHL: right heel-lift; LHL: left heel-lift; SA: shoulder abduction; RSF: right shoulder flexion; LSF: left shoulder flexion; DASI: Duke Activity Status Index.

DISCUSSION

This study explored the relationships among 3 different measures of physical fitness in adult patients with HF: exercise capacity, muscle function, and functional capacity. These measures were assessed with 3 valid and reliable instruments: the 6MWT, the MFT, and the DASI. Analysis revealed low-to-moderate correlations among these 3 variables. Principal component analysis grouped them into 2 factors: one related to lower limbs capacity and another related to upper limbs capacity. To our knowledge this is the first study to explore relationships among exercise capacity, muscle function, and functional capacity, and to explain the role of these measures in the assessment of physical fitness.

Measurement of the 6MWT in the current study was similar to that in previous studies on patients with HF (36, 37). Some studies have reported better performance, but the patients in those studies were younger and had fewer comorbidities (14, 20, 24, 38, 39).

Regarding muscle function, the scores were lower than those in other studies, mainly for isotonic shoulder flexion and shoulder abduction (12, 14, 40). This might be explained by the in-hospital recruitment for this study. The patients might have been more clinically compromised than outpatients. Heel-lift performance was similar or slightly lower compared with the findings of previous studies (12, 28, 40). As in the study by Cider et al. (12), the current study demonstrated a strong correlation between the results for the right and left limbs. It is possible that the patients might have remembered the number of contractions performed the first time; thus, they performed the same number the second time. The patient's choice to consider the number of completed contractions on the first attempt a goal to be achieved on the second attempt is beyond the clinician's control (12).

The mean DASI score in this study was similar to (17, 32), or higher than (4, 30, 41), those in other studies. The median score for dichotomizing the patients into high and low was significantly higher than the cut-off reported by Mantziari et al. (30), who used the sum of the 4 items of the DASI that were lower than 3 METs. The cut-off, 9.95 METs, reported for the study of Mantziari et al. represented empirically the minimum level of patient personal autonomy (taking care of himself or herself, walking 100 m, moving inside the home and performing light housework).

For exercise capacity, the correlation analysis showed a low-to-moderate positive correlation with all of the evaluations of the muscle function and functional capacity. This was in accordance with previous findings (14, 20). Borland et al. reported a low-to-moderate positive correlation between exercise capacity and muscle function (not for shoulder abduction evaluation) (14), and Myers et al. reported a moderate positive correlation between exercise capacity and functional capacity (0.44; $p<0.01$) (20). Moreover, a low positive correlation was found between functional capacity and muscle function. This confirmed, for the first time, that functional capacity was related to exercise capacity and muscle function.

NYHA class was found to be correlated with exercise capacity, muscle function, and functional capacity. This further confirmed the strong relationship between physical fitness measured in its multidimensionality and the functional classification assessed by the NYHA. Previous studies have reported that the NYHA class was related to functional capacity (4) and muscle function (27). According to another study (20), age was correlated with 6MWT, MFT and DASI, thus showing that older patients with HF had lower physical fitness.

Moreover, movement impairment was correlated with lower exercise capacity, muscle function and functional capacity (Table IV). Thus, as expected, physical fitness assessment could be influenced by movement impairment. It must be emphasized, therefore, that in patients with impairment of the lower limbs, physical fitness could be assessed if the patients were still able to perform tests with their upper limbs. For clinicians, this suggests that there are alternative ways to assess physical fitness in patients with HF.

As was reported by Dziubek et al., movement impairment can be the result of multiple factors, and it can reduce exercise capacity (42). Patients with HF who have movement impairment and comorbidities might have poorer performance in exercise capacity and muscle function for reasons other than HF (3, 4). This would be an interesting question for exploration in future studies.

In this study, exercise capacity, muscle function and functional capacity were measured by different, but correlated, aspects of physical fitness. The results show that there are commonalities among these measures even if the correlation coefficients were only low-to-moderate. This inconsistency in the results of the 6MWT, MFT and DASI was seen in 44% of participants. A possible explanation is the DASI, which uses self-reported data, unlike other more objective instruments used for assessment of exercise capacity and muscle function. Coutinho-Myrrha et al. reported a lower correlation between DASI and peak VO_2, if DASI is self-administered (43).

To detect the structure in the relationships between measures, principal component analysis was performed, and 2 factors were found. The first factor was based on the tests that involved mainly the lower limbs (6MWT, right heel-lifts and left heel-lifts in the MFT and DASI scores). The second factor was based on the tests that involved only the upper limbs (shoulder abduction, and right and left shoulder flexion). Interestingly, the DASI score loaded in the lower limb factor. This can be explained by the fact that the items ask about the ability to walk, climb stairs, walk up a hill, run, work around the house and play sports (18). This should be taken into account in research or clinical practice when assessing patients with impairment of the lower limbs. In such cases, clinicians and researchers should choose alternative methods proposed in the literature for assessing physical fitness (2, 5), especially in patients with HF, to avoid, for example, an inadequate evaluation of exercise capacity. Such strategy reduces the possible effect of movement impairment on physical fitness assessment.

A strength of the current study is the inclusion of patients with movement impairments, not compromising the inclusion criteria. Patients correctly recruited might have shoulder or knee pain that limits their real exercise capacity or muscle function, but still be able to perform exercise, according to the HF-Wii protocol (21). This allowed for exploration of the effects of movement impairment on the tests used to assess the patients' physical fitness. Among the limitations of this study are the in-hospital recruitment of patients; thus, generalizability is reduced because the results cannot be extrapolated to outpatients. Another limitation on the generalizability of the results is the preponderance of male patients in the sample. In fact, previous studies showed that incidence in patients with HF is equally distributed between men and women (44). Finally, the DASI questionnaire used for this study was not cross-cultural validated in Italian.

In conclusion, this study confirmed that physical fitness in patients with HF is multidimensional (2); therefore, the 3 measures used here can help clinicians to assess physical fitness in patients with HF more comprehensively. Exercise capacity, muscle function and functional capacity had a low-to-moderate relationship; thus, they are good methods for assessing patients' physical fitness even if the focus is different. These measures can be applied to the evaluation of patients with movement impairments because using only one instrument for physical assessment would be inadequate. As was reported in the literature, some instruments, such as the 6MWT, have strong predictive power for patients with HF, but are not appropriate for measuring the exercise capacity of patients who are unable to walk. In such cases, the MFT and the DASI could provide better information. Researchers and clinicians must be alert to the need to tailor an optimal test for each patient.

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