

PHYSICAL CAPACITY, RESPIRATORY AND PERIPHERAL MUSCLE STRENGTH IN HEART FAILURE

CAPACIDADE FÍSICA, FORÇA MUSCULAR RESPIRATÓRIA E PERIFÉRICA NA INSUFICIÊNCIA CARDÍACA

CAPACIDAD FÍSICA, FUERZA MUSCULAR RESPIRATORIA Y PERIFÉRICA EN INSUFICIENCIA CARDÍACA



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ABSTRACT

Introduction: The Glittre-ADL test is a submaximal test that involves sitting/lifting, stair climbing/descending, and weight-bearing activities, with considerable potential for use in assessing exercise intolerance in heart failure. **Objectives:** To investigate the influence of heart failure on maximal physical (ergometric test - ET) and functional (6MWT and Glittre-ADL test) capacity, on respiratory (IPmax and EPmax) and peripheral (handgrip strength) muscle strength, and to study the correlation between the variables evaluated. **Methods:** A prospective comparative study that assessed 44 subjects divided into two groups: G1, with 26 heart patients (20 men/6 women, 65.26 ± 8.50 years), and G2, with 18 healthy subjects paired with G1 on the basis of sex ratio, age and anthropometric characteristics (10 men/8 women, 60.72 ± 8.39 years). The comparison of categorical variables was performed using the chi-square test, while continuous variables were compared using the Student t test or Mann-Whitney test. The study of the correlation between variables was conducted using the Pearson coefficient for EPmax and handgrip strength, while the Spearman correlation coefficient was used for the others, with a statistical significance level of 5%. **Results:** Groups were homogeneous in terms of sex ratio, age and anthropometric characteristics. G1 had a worse performance in all tests: ET ($p = 0.016$), Glittre-ADL ($p = 0.001$), 6MWT ($p = 0.001$), IPmax ($p = 0.012$), EPmax ($p = 0.007$) and handgrip strength ($p = 0.036$). There was a negative correlation between the Glittre-ADL test and 6MWT, and the Glittre-ADL test and handgrip strength in G1. **Conclusion:** Heart failure resulted in impairment of maximal physical and functional capacity and of respiratory and peripheral muscle strength, with a negative correlation between functional capacity and handgrip strength. **Level of evidence II; Prospective comparative study.**

Keywords: Heart failure; Respiratory function tests; Cardiorespiratory fitness.

RESUMO

Introdução: O teste AVD-Glittre é um teste submáximo que envolve atividades de sentar/levantar, subir/descer degraus e sustentação de pesos, que tem grande potencial de uso na avaliação da intolerância ao esforço na insuficiência cardíaca. **Objetivos:** Pesquisar a influência da insuficiência cardíaca na capacidade física máxima (teste ergométrico - TE) e funcional (TC6 e teste AVD-Glittre), na força dos músculos respiratórios ($PI_{máx}$ e $PE_{máx}$) e periféricos (força de preensão palmar) e estudar a correlação entre as variáveis avaliadas. **Métodos:** Estudo prospectivo comparativo que avaliou 44 indivíduos divididos em dois grupos: G1, com 26 cardiopatas (20 homens/6 mulheres, 65,26 ± 8,50 anos) e G2 com 18 indivíduos saudáveis pareados com o G1 quanto à distribuição de sexo, idade e características antropométricas (10 homens/8 mulheres, 60,72 ± 8,39 anos). A comparação das variáveis categóricas foi realizada pelo teste do qui-quadrado e a das variáveis contínuas, pelo teste t de Student ou Mann-Whitney. O estudo da correlação entre variáveis foi feito pelo índice de Pearson para $PE_{máx}$ e força de preensão palmar; para as demais, pelo índice de correlação de Spearman, com nível de significância estatístico de 5%. **Resultados:** Os grupos foram homogêneos quanto à distribuição de sexo, idade e características antropométricas. O G1 apresentou pior desempenho em todos os testes: TE ($p = 0,016$), AVD-Glittre ($p = 0,001$), TC6' ($p = 0,001$), $PI_{máx}$ ($p = 0,012$), $PE_{máx}$ ($p = 0,007$) e força de preensão palmar ($p = 0,036$). Houve correlação negativa entre AVD-Glittre e TC6 e AVD-Glittre e força de preensão palmar em G1. **Conclusão:** A insuficiência cardíaca resultou em comprometimento da capacidade física máxima, funcional e da força muscular respiratória e periférica, com correlação negativa entre capacidade funcional e força de preensão palmar. **Nível de Evidência II; Estudo Prospectivo e Comparativo.**

Descritores: Insuficiência cardíaca; Testes de função respiratória; Aptidão cardiorrespiratória.

RESUMEN

Introducción: La prueba AVD-Glittre es una prueba submáxima que implica sentarse/pararse, subir/bajar escalones y actividades con carga de peso, que tiene un gran potencial para uso en la evaluación de la intolerancia al estrés en la insuficiencia cardíaca. **Objetivos:** Investigar la influencia de la insuficiencia cardíaca en la capacidad física máxima (prueba ergométrica - PE) y funcional (prueba 6MWT y AVD-Glittre), en la fuerza de los músculos respiratorios ($PI_{máx}$ y $PE_{máx}$) y periféricos (fuerza de agarre manual) y estudiar la correlación entre las variables evaluadas. **Métodos:** Estudio prospectivo comparativo que evaluó a 44 individuos, divididos en dos grupos: G1, con 26 cardíacos (20 hombres/6 mujeres, 65,26 ± 8,50 años) y G2 con 18 individuos sanos emparejados con G1 con respecto a la distribución de sexo, edad y características antropométricas (10 hombres/8 mujeres, 60,72 ± 8,39 años). La comparación de las variables



categorías se realizó utilizando la prueba de chi-cuadrado y la de variables continuas, utilizando la prueba t de Student o Mann-Whitney. El estudio de la correlación entre variables se realizó utilizando el índice de Pearson para $PE_{máx}$ y fuerza de agarre manual; para las demás, se utilizó el índice de correlación de Spearman, con un nivel de significación estadística del 5%. Resultados: Los grupos fueron homogéneos en cuanto a la distribución por sexo, edad y características antropométricas. El G1 presentó el peor desempeño en todas las pruebas: PE ($p = 0,016$), AVD-Glittre ($p = 0,001$), 6MWT ($p = 0,001$), $PI_{máx}$ ($p = 0,012$), $PE_{máx}$ ($p = 0,007$) y fuerza de agarre manual ($p = 0,036$). Hubo una correlación negativa entre AVD-Glittre y 6MWT y AVD-Glittre y la fuerza de agarre manual en G1. Conclusión: La insuficiencia cardíaca resultó en un deterioro de la fuerza muscular máxima, funcional y respiratoria y periférica, con una correlación negativa entre la capacidad funcional y la fuerza de agarre manual. **Nivel de Evidencia II; Estudio Prospectivo y Comparativo.**

Descriptor: Insuficiencia cardíaca; Pruebas de función respiratoria; Capacidad cardiovascular.

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INTRODUCTION

Exercise intolerance in heart failure (HF) is associated with central cardiovascular involvement and skeletal muscle changes.¹ Such changes result from neurohormonal system modulation; exacerbation of the muscular sympathetic nervous system; renin-angiotensin-aldosterone system activation,² oxidative stress, muscle apoptosis and immune system activation (release of cytokines).³ These adaptations also occur in the respiratory muscles and predispose HF patients to early-onset fatigue and dyspnea and limited physical capacity.

Cardiopulmonary exercise testing is the gold standard for defining exercise intolerance in HF. However, it involves high costs and requires specialized professionals. Thus, other submaximal tests have been applied and show a good correlation with maximal tests.⁴ The 6-minute Walk Test (6MWT) is an example. However, the reproduction of Activities of Daily Living (ADL) is scaled down to the act of walking alone. In this manner, other tests that assess functional capacity in a more comprehensive way have been described. Such tests include the Glittre-ADL Test, which involves, in addition to walking, activities such as sitting and standing up, climbing and descending stairs, and arm movements with weight-bearing. This test was originally described in COPD patients.⁵ Although COPD and chronic heart failure are anatomically and pathologically distinct, exercise intolerance, dyspnea and fatigue are common alterations in these conditions. Abnormalities in structure, lung function and peripheral impairment occur in both.⁶ Changes in the ventilation/perfusion ratio with a consequent gas exchange deficit are present in both diseases, and in HF are caused by impaired cardiac pump function, increased left atrial pressure, and pulmonary congestion.⁷ Thus, the purpose of this study was to investigate the influence of stable chronic heart failure on maximal and functional physical capacity, on respiratory muscle strength, and on the correlation between the variables studied.

MATERIALS AND METHODS

An observational cross-sectional study, approved by the UFMS Institutional Review Board (37934714.7.0000.0021), in which 44 subjects of both sexes participated. The subjects signed an informed consent form and were divided into two groups: G1: 26 chronic heart disease patients (20 men and 6 women, mean age 65.26 ± 8.50 years) and G2: 18 healthy subjects paired with G1 on the basis of sex ratio, age and anthropometric characteristics (10 men and 8 women, with a mean age of 60.72 ± 8.39 years). G1 participants were recruited from the Cardiac Rehabilitation Clinic of the Hospital Regional de Mato Grosso do Sul, with NYHA HF functional classification (FC) I, II and III, stages B and C, and hemodynamically stable. G2 was composed of volunteers recruited from the academic institution and community.

The study included individuals with clinical conditions that could not be exacerbated by physical exertion, without medical contraindication to exercise, and without cognitive deficit, hypertrophic cardiomyopathy, unstable angina, dyspnea at rest, acute myocardial infarction and/or cardiac surgery performed less than six months previously, lung diseases, or limitations that would interfere with mobility. Each study participant was assessed at four time points (on alternate days), with a random order in the application of the tests: 1- pulmonary function assessment and anthropometric assessment; 2- ergometric test; 3- Glittre-ADL test and 4- 6MWT.

The following data were verified in the anthropometric assessment: weight using Welmy[®] mechanical scale for adults (São Paulo/SP/Brazil), height: aluminum 2.00 m scale ruler for anthropometric measures according to the Rocha⁸ method, BMI (weight in kilograms/height² in meters⁸), and waist-hip ratio.⁹

Ergometric tests were carried out by a cardiologist, in a laboratory with controlled temperature and relative humidity.¹⁰ The ramp-adapted Bruce protocol was applied in both groups. 12-lead electrocardiogram (ECG) findings were recorded at rest, obtained in the supine position and in three modified leads, CM5, aVF and V2, in the orthostatic position and during the test, using the computerized system Ergo-PC 13 for Windows and a Micromed Centurion 300 treadmill (São Paulo/SP/Brazil). The estimated indirect measurement of maximal oxygen uptake (VO_{2max}) in METs was calculated using the Foster formula with handrail support, with $VO_2: 0.69 \times VO_2 (ACSM) + 3.330$, where ACSM stands for the American College of Sports Medicine formula.¹¹

The 6MWT was conducted in a flat corridor measuring 30 meters in length according to ATS recommendations.¹² The parameters of normality for the distance covered in the 6MWT were determined using the equations proposed by Iwama et al.¹³ Two tests were performed at least 30 min apart, and in the case of a difference greater than 10% between distances, a third test was performed.

The Glittre-ADL test was carried out as recommended by Skumlien et al.⁵ To summarize, we clocked the time spent to cover five laps of a circuit, during which time the study participants carried a rucksack on their backs (2.5 kg for women and 5 kg for men), walked, climbed and descended steps, and moved 1 Kg objects on a rack with shelves. The time spent was compared with the time predicted using the equation proposed for the Brazilian population.¹⁴ Two tests were performed with a 30-minute interval, and in the case of a difference greater than 10% between distances, a third test was performed.

Respiratory muscle strength was obtained by measuring maximum respiratory pressures with the use of the MVD300 manometer (Globalmed, Porto Alegre/RS/Brazil). The method and the normality references used were those proposed by Neder et al.¹⁵

Peripheral muscle strength

Peripheral muscle strength was assessed by measuring handgrip strength, using the Saehan[®] dynamometer (Saehan Corp. MASAN, Korea). The method used was that described by the American Association of Hand Therapists (FESS),¹⁶ and the reference values by age and sex were consistent with those established by Bohannon and Schaubert.¹⁷

Statistical analysis

SPSS 20.0 software was used. The Chi-squared test was used for categorical variables and the Student's *t*-test or Mann-Whitney test to compare the continuous variables. Either Pearson's coefficient or Spearman's correlation coefficient was used to analyze the correlation between the variables studied. The level of statistical significance used was $p < 0.05$.

RESULTS

The anthropometric characteristics of the sample are described in Table 1, which shows that the groups were homogeneous in terms of sex ratio, age, and anthropometric characteristics.

The clinical characteristics of G1 are listed in Table 2, which shows that functional class I and stage C were more frequent. The mean LVEF of G1 was $35.00 \pm 14.97\%$. Regarding the etiology of chronic heart failure, we observed a predominance of ischemic cardiomyopathy, followed by dilated cardiomyopathy.

The results of the tests that evaluated maximal physical capacity and functional capacity are described in Table 3. In all tests, the majority of G1 was classified as having a reduced result, while in G2, the majority was considered normal, with a significant difference for all 3 tests: ET ($p = 0.016$), Glittre-ADL ($p = 0.001$) and 6MWT ($p = 0.001$).

In G2, nine volunteers did not undergo the ET and two did not undergo the Glittre-ADL test as they were unable to get time off work.

Table 1. Anthropometric characteristics of the two groups studied.

Parameters	G1	G2	Statistical test	P
Sex	n (%)	n (%)	Chi-squared	
Female	6 (23.07%)	8 (44.44%)	2.24	0.135
Male	20 (76.92%)	10 (55.50%)		
Age			T test	
	$65.26 \pm 8.50^*$	$60.72 \pm 8.39^*$	1.75	0.087
BMI			T test	
	$29.96 \pm 5.28^*$	$28.04 \pm 4.91^*$	1.22	0.227
W/HR			Mann Whitney	
	$0.96 \pm 0.11^†$	$0.93 \pm 0.12^†$	176.50	0.169

BMI - body mass index; W/HR - waist / hip ratio; (*) mean and standard deviation; (†) median and interquartile range.

Table 2. Clinical characteristics of the HF patients studied (G1).

	n (LVEF%)	(%)
Functional class		
I	12 (39,17 ± 9,81)*	46,15
II	10 (34,70 ± 11,15)*	38,46
III	04 (26,66 ± 8,52)*	15,38
Stage		
B	3	11,53
C	23	88,46
Disease etiology		
Ischemic cardiomyopathy	13	50,00
LV dilated cardiomyopathy	07	26,92
Alcoholic cardiomyopathy	03	11,53
Chagasitic dilated cardiomyopathy	03	11,53

Class I - asymptomatic in ordinary activities; Class II - asymptomatic at rest with symptoms triggered by accustomed exertion; Class III - asymptomatic at rest with symptoms present on less than usual exertion. Stage B - patients who have acquired a structural cardiac injury, but still without symptoms attributable to heart failure; Stage C - patients with a structural cardiac injury and current or past symptoms of heart failure. LVEF% - left ventricular ejection fraction, expressed as mean and standard deviation(*).

Of the seven volunteers who underwent the ET, only 14.2% showed a reduction and 85.7% had normal results in the test. In G1, one patient did not complete the 6MWT due to an orthopedic restriction. Thus, 24 patients completed the 6MWT.

The results in terms of the respiratory muscle strength and handgrip variables of both groups studied are described in Table 4, which shows that the majority of G1 participants had a reduction in IPmax ($p = 0.012$), EPmax ($p = 0.007$) and dynamometry ($p = 0.036$), with a statistically significant difference in comparison to G2.

The study of the correlation between the variables studied in G1 is represented in Table 5. A significant negative correlation was observed between the Glittre-ADL and 6MWT tests, and the Glittre-ADL test and handgrip strength. There was also a significant positive correlation between the ET and 6MWT.

Table 3. Statistical analysis of the following tests: ergometric, Glittre-ADL and Six-minute walk test in the two groups studied.

Tests conducted	G1	G2	Statistical test	p
ET			Chi-squared	0.016
Normal	n= 10 (38.46%)	n= 9 (81.81%)	5.81	
Reduced	n= 16 (61.53%)	n= 2 (18.18%)		
GLITTRE-ADL			Chi-squared	0.001
Normal	n= 5 (19.23%)	n= 12 (75.00%)	12.78	
Reduced	n= 21 (80.76%)	n= 4 (25.00%)		
Time spent on Glittre-ADL			Mann Whitney	0.001
Median	3.33	2.47	77.0	
Interquartile	1.34	0.88		
6MWT			Chi-squared	0.001
Normal	n= 4 (16%)	n= 13 (72.22%)	13.838	
Reduced	n= 21 (84%)	n= 5 (27.77%)		

ET - ergonomic test; n= number of individuals; Glittre-ADL: Glittre's Activity of Daily Living Test; 6MWT - six-minute walk test.

Table 4. Statistical analysis of respiratory muscle strength and peripheral muscle strength of the two groups studied.

Variables	G1	G2	Statistical test	p
IPmax		Chi-squared		
Normal	05 (29.23%)	10 (55.25%)	6.24	0.012
Reduced	21 (80.76%)	08 (44.44%)		
EPmax		Chi-squared		
Normal	08 (30.76%)	13 (72.22%)	7.32	0.007
Reduced	18 (69.23%)	05 (27.77%)		
Dynamometry		Chi-squared		
Normal	12 (46.15%)	14 (77.77%)	4.40	0.036
Reduced	14 (53.84%)	04 (22.22%)		

IPmax- Maximum inspiratory pressure; EPmax- Maximum expiratory pressure; 6MWT- six-minute walk test; ET-ergometric test.

Table 5. Statistical analysis of the correlation between variables studied in the HF group (G1).

	IPmax	EPmax	6MWT	Glittre-ADL	ET	Handgrip strength
IPmax	1.00					
EPmax	0.183	1.00				
6MWT	0.259	0.278	1.00			
Glittre-ADL	- 0.348	- 0.057	- 0.484*	1.00		
ET	- 0.092	0.024	0.409*	- 0.108	1.00	
Handgrip strength	0.270	0.153	0.274	- 0.607*	- 0.044	1.00

*Significant correlations ($p < 0.05$); IPmax- maximum inspiratory pressure; EPmax- maximum expiratory pressure; 6MWT - six-minute walk test; Glittre-ADL test - Glittre's activities of daily living test; ET- ergometric test.

DISCUSSION

Individuals with stable chronic heart failure investigated in this particular study showed impairment of maximal physical capacity, functional capacity and respiratory and peripheral muscle strength, in comparison to the group of healthy individuals studied. This reinforces the negative influence of peripheral and respiratory muscle impairment characteristic of heart failure on the performance of activities of daily living and on maximal physical capacity.¹⁸ Histological, metabolic and functional changes in skeletal muscle, including respiratory musculature, due to HF, result in early-onset fatigue and dyspnea and consequent limitation of functional capacity. Maximum inspiratory pressure is related to HF severity and ventilatory limitation during exercise, in addition to being a prognostic indicator of HF.¹⁹

Studies report a reduction in peripheral and respiratory muscle strength in HF patients.^{20,21} Such functional changes in the inspiratory musculature may result in exacerbation of the metaboreflex induced by the work of the inspiratory musculature and the exaggerated increase in ventilation mediated by the chemoreflex during exercise.²² The assessment of activities of daily living can be performed by direct observation, by applying questionnaires or scales that are inexpensive and user-friendly, yet subjective and less accurate, or by applying submaximal tests, such as: the 6MWT, Glittre-ADL test and Shuttle Walk Test (SWT).²³

The cardiopulmonary exercise test has established a reputation as the reference standard for the objective measurement of functional capacity and stratification of heart failure patient prognosis. However, this is a high-cost technique that requires sophisticated equipment and specialized manpower, and is only found in certain centers; in addition, it requires greater patient collaboration.⁴ Due to the widespread availability, safety, and ease of execution of the 6MWT, this test is increasingly being used as an alternative to the CPT to assess the functional capacity of HF patients. This test has proven useful and reliable in assessing the functional capacity, prognosis and therapeutic efficacy of patients with this syndrome.²⁴ However, it is worth mentioning that, through the 6MWT, ADL capacities are restricted to the act of walking.

In order to represent ADLs in a more realistic manner, new scientific instruments have been proposed. In 2006, the Glittre-ADL test was developed by Skumlien et al.⁵ to assess the limitation in ADL of COPD patients. Although COPD and chronic heart failure are anatomically and pathologically distinct, exercise intolerance, dyspnea and fatigue are common alterations in these conditions.⁶

The main advantages of the Glittre-ADL test are that it requires little space, is easy to apply, and simulates activities besides walking, such as climbing and descending stairs, sitting down and getting up from a chair, and the performance of weight-bearing movements with the upper limbs and trunk flexion. This inclusion of activities that use both upper and lower limbs reflects the limitations of activities of daily living more accurately than the 6MWT.²⁵ These advantages make the Glittre-ADL an assessment tool with excellent clinical viability prospects for individuals with heart failure.²⁶

The Glittre-ADL test has already proven to be a user-friendly, valid and reliable tool for measuring functional status in patients with COPD;^{5,26,27} applicable in the assessment of limitation in activities of daily living (ADL) in subjects with heart failure, class III and IV;²³ and able to distinguish between the functional status of healthy individuals and those with COPD.²⁵ It has also shown a relationship with sitting and walking time in patients with COPD, and a physiological response similar to the 6MWT, with a slight increase in oxygen consumption.²⁷

Regarding the use of the Glittre-ADL test in patients with HF, to date, only three national studies^{23,28,29} and no international studies have been found.

Valadares et al.²³ conducted a study to verify the applicability of the London Chest Activity of Daily Living (LCADL) scale and the Glittre-ADL test (GlittreT) in the assessment of the functional limitation of individuals with functional class III and IV HF. Ten patients with HF (57 ± 9 years; 27.5 ± 4.5 kg/m²) of both sexes, with functional class III and IV and left ventricular ejection fraction (LVEF) $34 \pm 7\%$ participated in the study. As regards results, the authors describe a positive correlation between the score of the total LCADL scale and time of the Glittre-ADL test, and state that the Glittre-ADL test was negatively correlated with the 6MWT, LVEF and functional capacity category of the SF-36 questionnaire.

Chiodelli et al.²⁸ studied the relationship between respiratory and peripheral muscle strength and functional limitation in nine patients with heart failure (age 53.5 ± 6 years, NYHA functional class II and III and LVEF $26.2 \pm 8.1\%$). As regards results, the authors reported that the HF patients studied had reduced inspiratory, expiratory and lower limb muscle strength. However, the time spent on the Glittre-ADL test showed a strong correlation only with quadriceps muscle strength. Chiodelli et al.²⁸ also observed a strong negative correlation ($r = -0.81$) between the Glittre-ADL test and the 6MWT.

Fernandes-Andrade et al.²⁹ investigated whether the Glittre Test is able to discriminate the functional status of patients with cardiovascular diseases. Forty-two individuals (62.21 ± 12.07 years) were assessed using the Glittre-ADL and SWT tests, the Human Activity Profile (HAP) and the Duke Activity Status Index (DASI). The execution time of the Glittre-ADL test was compared with the different ranges of the SWT, HAP and DASI tertiles. The authors report a statistically significant difference in the execution time of the Glittre-ADL test between the tertiles of the SWT ($p = 0.0001$), between the tertiles of the three tests studied, thus demonstrating that the Glittre-ADL test is able to distinguish between functional classes of individuals with CVD, especially in relation to individuals with greater functional impairment.

It is noteworthy that the national studies by Valadares et al.,²³ and Chiodelli et al.,²⁸ reported a negative correlation between the time spent on the Glittre-ADL test and the 6MWT, and that the study by Fernandes-Andrade et al.²⁹ also showed that the Glittre-ADL test is able to recognize differences in the functional capacity of patients with cardiovascular diseases. These results are consistent with our findings from this particular study. Therefore, we can suggest that the Glittre-ADL test really is an instrument with considerable potential for use to assess functional capacity in HF patients.

CONCLUSIONS

In the sample studied, heart failure resulted in impaired maximal and functional physical capacity and impaired respiratory and peripheral muscle strength, with a significant negative correlation between functional capacity and handgrip strength.

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