**"CAROL DAVILA" UNIVERSITY OF MEDICINE AND PHARMACY, BUCHAREST**

**DOCTORAL SCHOOL**

**FIELD: MEDICINE**

# CONSIDERATIONS ON THE ASSESSMENT OF HEART FUNCTIONAL CAPACITY USING THE INSTRUMENTED ANALYSIS OF MOVEMENT AND PREHENSION FORCE (GRIP STRENGTH) IN PATIENTS WITH NYHA CLASS II-III CHF

**SUMMARY of PhD THESIS**

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# Content

# 1. Assessment of hand grip strength using Amadeo robot in patients with class II-III NYHA heart failure

## 1.1. Assumptions and objectives

Heart failure is a common pathology in elderly who are physically deconditioned. The prevalence of sarcopenia in patients with heart failure is higher than it is believed; therefore, it is important to correctly evaluate patients with heart failure in order to include them early in rehabilitation programs. Thus, we avoid the creation of a vicious circle between sarcopenia and heart failure.

Measuring hand grip strength is a useful tool in assessing the physical deconditioning. By measuring the flexion and extension forces of the hand, we can determine the prehension force (grip strength). There are studies analyzing the link between hand grip strength and mortality, hospitalization and life quality rates [1].

Although we do not have reference values for the assessment of hand flexion and extension forces in patients with heart failure, we believe that a correct and quick assessment provides an overview and valuable information on the degree of physical deconditioning of patients with heart failure. It is also a useful tool for integrating patients into rehabilitation programs.

Using Amadeo robot when evaluating the flexion and extension forces of the hand can represent an effective method in quantifying the prehension force of the hand. Thus, we can establish whether or not the patient with heart failure features a functional capacity decrease.

## 1.2. Patients and methods

We prospectively analyzed a group of 44 patients with NYHA class II-III heart failure, admitted to the Cardiology Department of the Elias University Emergency Hospital during June 17, 2019 and July 15, 2020.

Inclusion criteria:

- hemodynamically and electrically stable patients with heart failure;
- patients over 18 years who gave written consent for the participation to the study.

Exclusion criteria:

- neurological impairment;;
- cognitive impairment;

- neoplasias;
- blindness;
- acute coronary syndromes;
- TEP;
- lack of written consent.

Patients were evaluated with the help of the Amadeo robot, both immediately after the compensation of the acute phase of heart failure and on the day before discharge. We measured the hand flexion and extension force (expressed in kilograms) using Amadeo robot.

Amadeo is a manual therapy device that uses tyro S software and offers a wide range of hand and finger therapies. It can be adjusted for each patient.

Amadeo robot is a device that associates sensors attached to the hand and fingers and is used especially in physical rehabilitation programs for stroke patients [2].

This robot is able to measure the hand flexion and extension forces due to the sensors attached to the fingers. This force is expressed in kilograms and thus evaluates the grip strength of the hand. Amadeo robot can be used as therapy in patients with spasticity or high tonus of the hand.

Amadeo is the world's most advanced device used in robotic finger-hand therapy. It helps to improve motor and sensory functions and provides a remediation in the synapse neo-formation by the movement of the fingers.

Functionality of this robot includes [3]:

o measurement of tonus and spasticity;

o therapies for spasticity and physical training meant to develop sensitivity;

o improved assessment of the force actively practiced by the patient as well as the range of active movement;

o simulation of the hand gripping natural movement;

o passive hand movement therapy (the passive hand is stimulated);

o hand assistance therapy: functions shown on the display allow active physical training according to the patient's performance limit;

o interactive therapies: active physical training with specially developed virtual therapy games;

o choosing a therapy program adapted to each patient, according to the degree of his/ her neurological impairment; the patient can be treated passively or actively.

Parameters monitored during the study are the following:

- hand flexion force;
- hand extension force;
- age;
- sex;
- weight;
- height;
- risk factors: smoker/ non-smoker, hypertension, dyslipidemia, type II diabetes
- other associated pathologies;
- echocardiographic data;
- biological parameters (oxygen saturation, hemoglobin, blood sugar, creatinine, sodium, potassium).

Assessment was performed using the patient's dominant hand. Clinical and paraclinical data were collected from the medical history with the consent of the attending physician.

We had been making associations between risk factors (age, sex, hypertension, type II diabetes, dyslipidemia, smoking status), associated pathologies (valvulopathies, coronary heart disease, atrial fibrillation) and hand flexion and extension forces in hospitalized patients with heart failure and tried to see to what extent hand mobility is affected by these risk factors and associated pathologies.

## 1.3. Results

### 1.3.1. Assessment of hand extension force using Amadeo robot

Further to patients' assessment upon admission with the help of Amadeo robot, it was noticed that they had an average hand extension force value of 2.364 kg, while upon discharge the value was higher: 2.264 kg, i.e. p-value of 0.4507.

In male patients, the average value of the extension force was 2.5kg, and in female patients, the average value was 2.3kg, i.e. p-value=0.1877. Patients with valvulopathies had an average extension force of 2.250 kg, while those without valvulopathies had an average extension force of 2.6 kg, i.e. p-value=0.03396, which is a significant value in our analysis. Patients with arterial hypertension proved an average extension force value of 2.4 kg, while the ones with normal heart rate proved an average extension force value of 1.8 kg, i.e. p-value=0.05256. Patients with atrial fibrillation had an average extension force of 2.3kg, while those with no atrial fibrillation had an average value of 2.5kg, i.e. p-value=0.7667. A hand extension force of 2.45 kg was noticed in patients with ischemic heart disease. Patients who were not suffering from ischemic heart disease had a slightly lower value of 2.3kg, i.e. p-value=0.437. Diabetic patients had an average extension force value of 2.550kg, while non-diabetic patients had an average value of 2.3kg, i.e. p-value=0.2017. Smokers showed an average extension force value of 2.5kg, while the non-smokers showed an average extension force value of 2.3kg, p-value = 0.6613. Patients with dyslipidemia proved an average extension force value of 2.4 kg. Patients without dyslipidemia proved an average extension force value of 1.65 kg, i.e. p-value=0.05722. Patients with mitral or aortic insufficiency recorded an average extension force value of 2.3 kg, and those without mitral or aortic insufficiency had an average extension force value of 2.45 kg, i.e. p-value= 0.8069. The average hand extension force was 2.5 kg in patients with aortic stenosis, and 2.35 kg in patients who were not suffering from aortic stenosis, i.e. p value=0.5718. In terms of the biological parameters (hemoglobin, creatinine, Na, K), no relevant values were noticed during our study because the p-value was far above the threshold of statistical significance.

#### 1.3.2. Assessment of hand flexion force using the Amadeo robot

Average hand flexion force value of heart failure patients was 6.78kg upon admission, while upon discharge it was 7.361kg, i.e. p-value=0.02216.

We have been analyzing the association between hand flexion strength and associated risk factors/ pathologies in patients with heart failure. The average hand flexion force in female patients was 5.7 kg, and the average hand flexion force in male patients was 8 kg, i.e. p-value =0.004962. Patients with valvulopathies had an average flexion force value of 6.350 kg and those with no valvulopathies had an average value of 6.550 kg, i.e. p-value= 0.236. The hypertensive patients showed an average flexion force value of 6.3 kg, while non-hypertensive ones showed the average value of 8 kg, i.e. p-value=0.6836. Patients with atrial fibrillation had an average flexion force of 6.4kg, and those with no trial fibrillation recorded an average of 6.3kg, i.e. p-value= 0.776. Patients with ischemic heart disease had an average flexion force value of 6.250 kg, while those with no ischemic heart disease had an average value of 6.6 kg, i.e. p-value=0.4376. The average flexion force value was identical in diabetic patients and in non-diabetic ones, i.e. 6.350 kg (p-value=0.6948). Smokers had an average flexion force value of 7kg, while non-smokers had an average flexion force value of 6.1kg, i.e. p-value=0.09687. In patients with dyslipidemia, the average flexion force value was 6.450 kg, and in those without dyslipidemia, it was 5.050 kg, i.e. p-value=0.3555. Patients with mitral/ aortic insufficiency recorded an average flexion force value of 6.3 kg, while patients with none of such valvulopathies had an average flexion force value of 6.35 kg, i.e. p-value=0.5498. Patients with aortic stenosis had an average hand flexion force value of 7.35 kg, while those without this pathology recorded an average value of 6.250 kg, i.e. p= 0.5958.

In terms of biological parameters (hemoglobin, creatinine and K), no statistically significant associations related to the hand flexion force were noticed. The only biological parameter that showed a statistically significant change was Na. Consequently, it was noticed that a low value of sodium is associated with a low flexion force value (p-value = 0.0426).

### 1.4. Conversations

Amadeo robot in patients with heart failure is a safe and effective method in assessing hand flexion and extension forces. This study aimed to assess the hand grip strength in patients with heart failure and especially to establish the role that risk factors and associated pathology have on the patient's physical deconditioning.

It was noticed during our study that smokers proved better flexion and extension force values than non-smokers. This result can be explained by the fact that smokers were younger than non-smokers. Consequently, they had a better physical condition and fewer comorbidities. Men showed a much better value than women, both for flexion and extension of the hand and this result is deemed normal from a physiological point of view. Patients with valvulopathies featured a slightly lower value compared to those without valvulopathies both in terms of hand flexion and hand extension.

Hypertension had a negative influence on the flexion strength of the hand because flexion strength in hypertensive patients was lower than in normotensive patients.

It was noticed that the hand extension force is slightly lower in patients with atrial fibrillation than in case of those without this pathology. Patients with ischemic heart disease recorded a much lower value of the hand flexion force compared to those without ischemic heart disease.

As for diabetes, no significant associations were noticed during the analysis. The weak statistical power can be explained by the small number of patients studied.

Amadeo robot is used especially for stroke patients. There are studies showing that the use of Amadeo robot in stroke patients improves both the motor function of the hand and the cognitive function due to the ability to re-form the synapses [4].

In the initial phase, after the onset of a stroke, the intensive use of Amadeo robot in the hand recovery function showed favorable results and we saw an improvement of the motor deficit in these patients. An increase in strength was noticed in both the flexor and extensor muscles after 20 robotic treatment sessions alongside the classical treatment [5].

Data in the specialty literature show a wider remodeling of the sensuous-motor plasticity of patients who underwent rehabilitation using Amadeo robot. It was noticed an improvement in both the clinical condition and the neurophysiological part of these patients. The use of Amadeo robot in the recovery process of stroke patients proved superior to conventional exercises [6].

Hand grip strength is associated with fragility, patient comorbidities and increased risk of cardiovascular events. Hand strength measurement can be useful in identifying fragility among patients with cardiovascular disease. These patients' frail status assessed by measuring the muscle strength of the hand can be associated with comorbidities, sarcopenia and increased risk of cardiovascular events. These findings suggest that hand strength measurement can be used as a simple and safe screening tool in patients with cardiovascular pathology [7].

Also, there have been conducted studies showing that a low hand grip strength value among the healthy population is associated on a long term with an increased risk of developing cardiovascular diseases [8].

Also, studies have shown that sarcopenia equally affects elderly heart failure patients with both low ejection fraction and preserved ejection fraction and it represents an important mortality predictor [9].

Sarcopenia is of particular clinical importance in patients with heart failure because it is closely related to the severity of the disease, functional capacity and prognosis. Natriuretic peptide levels were significantly increased in patients with heart failure and sarcopenia compared to those with no symptoms of sarcopenia. Sarcopenia was associated with a more advanced stage of the disease [10].

A study performed in Portugal showed that the use of statins can have a beneficial effect on both heart failure and sarcopenia. A possible explanation is the pleiotropic effects of statins on endothelial function [11].

Other studies have got to the conclusion that prevalence of sarcopenia in obese/ overweight heart failure patients is similar to that of skinny sarcopenic patients [12].

Studies have shown that muscle mass loss occurs more frequently in elderly patients with heart failure as it is associated with higher mortality [13].

Considering the increase in life expectancy, the age of heart failure patients is getting more advanced. Thus, geriatric impairments become an important problem to treat because they lead to low mobility, multiple disabilities and cognitive fall. Frailty is a common clinical syndrome in geriatric patients and shows the decrease in physiological reserve and resistance to stress factors. Frailty is common in patients with heart failure, especially in elderly patients [14].

### 1.4. Conclusions

Further to the study that monitored 44 patients with NYHA class II-III heart failure and used Amadeo robot to evaluate the flexion and extension forces of the hand, we can say that risk factors and associated pathologies such as hypertension, type II diabetes, dyslipidemia, ischemic heart disease, atrial fibrillation, valvulopathies, smoking and age can have a significant influence on hand mobility. Heart failure patient is a fragile patient with multiple comorbidities. Deconditioning in patients with heart failure represents the effect of the basic disease, but it also represents the cause of comorbidities preservation. Low mobility is associated with an increased risk of cardiovascular diseases.

Main purpose of rehabilitation is to restore lost skills, to increase the patient's quality of life, to improve mobility and, thus, to decrease cardiovascular risk, mortality and morbidity in a long term. The first step in the rehabilitation process of patients with cardiovascular pathology is the correct assessment of functional capacity and the documentation of sarcopenia.

Results of the study show us that Amadeo robot can be used successfully in assessing the functional capacity of patients with cardiovascular pathology. Sarcopenia assessment can also be performed using this robot.

# 2. Assessment of walking speed and movement speed using G-WALK device in patients with NYHA class II-III heart failure

## 2.1. Assumptions and objectives

Heart failure is a high-incidence pathology considering the increase in life expectancy. The population aging phenomenon also brings on an increase in the incidence of cardiovascular diseases, which is the main cause of mortality and morbidity. The geriatric patient is a fragile, physically deconditioned patient affected by sarcopenia. Sarcopenia and frailty are important markers in the assessment of the geriatric patient with heart failure, which can negatively influence the mortality rate and the quality of life.

We can see physiopathological changes at the level of muscle mass in patients affected by sarcopenia, which are: muscle mass dysfunction and/or decrease in skeletal muscle mass. These changes result in a decrease of physical performance and, by default, of the quality of life.

Correct diagnosis of sarcopenia and the inclusion of patients affected by sarcopenia in physical rehabilitation programs must represent a priority in the treatment of patients with heart failure, along with medical and surgical treatment.

Main objective of the study was to assess the functional mobility of the heart failure patient using the G-WALK device.

Secondary objectives of the study were represented by:

- performing associations between cardiovascular risk factors and the walking and mobility test results;

- identifying the comorbidities that can influence the decrease in the physical performance of the heart failure patient.

## 2.2. Patients and methods

We prospectively analyzed a cohort of 44 patients admitted to Elias University Emergency Hospital, Cardiology department during June 17, 2019 and July 15, 2020.

Inclusion criteria:

- hemodynamically and electrically stable heart failure patients;

- age over 18 years;
- written consent on the participation in the study.

Exclusion criteria:

- stroke in the medical history;
- neoplasias;
- acute coronary syndromes;
- pulmonary thromboembolism;
- cognitive impairment;
- visual disturbances.

We evaluated hospitalized heart failure patients using the G-WALK device both at the time of acute phase compensation and at the time of discharge. The parameters measured with the G-WALK device were:

1. WALK test - which measures walking speed (expressed in m/s);

2. TUG test - which measures mobility (expressed in seconds).

We made associations between the results gathered upon hospitalization and the results gathered upon the discharge of the patients. Other monitored parameters were: age, sex, risk factors (smoker/ non-smoker, hypertension, dyslipidemia, type II diabetes), personal pathological history (coronary heart disease, atrial fibrillation, valvulopathies) and biological parameters (hemoglobin, creatinine, Na, K, blood sugar).

G-WALK device is composed of a wireless sensor, which analyzes the patient's walking speed, mobility and balance. The evaluated parameters are transmitted via bluetooth to a G-STUDIO software system where they are analyzed. G-WALK device includes a wireless tri-axial accelerometer that analyzes the patient's walking by measuring both walking speed and mobility.

WALK test measures the walking speed of patients by a sensor belt. It is attached at lumbar level. The test was performed in the corridor of the Cardiology department and the patient had to walk a distance of 2x6 meters and make a turn. Patients were instructed to walk at a comfortable pace and to inform the study examiner of the occurrence of any symptoms. Normal walking speed was considered to be >0.8m/s, while a low walking speed was considered to be <0.8m/s.

Timed Up and Go (TUG) test measures patients' mobility and balance. Patients are seated on a 45 cm heigh chair; the same wireless sensor belt is used. Patients are asked to stand up, walk 3 meters and sit back on the chair. The time the patient performs this test is measured and written down in seconds.

It takes into account the following:

- normal mobility - TUG test value < 15 s;

- slightly reduced mobility - TUG test value 15-25 s;

- moderately reduced mobility - TUG test value > 25 s;

- severely impaired mobility - the patient cannot perform the test until the end.

There are studies that focus on the functionality of G-WALK device use when analyzing the mobility of heart failure patients. These studies showed that G-WALK device is extremely useful and reliable in assessing the physical capacity of heart failure patients. It could successfully replace the use of the 6-minute walk test [15].

### 2.3. Results

#### 2.3.1. WALK test

Average walking speed of the studied group was 0.8416 m/s upon admission and 0.8805 m/s upon discharge, i.e. p-value=0.09449.

Upon admission, 23 heart failure patients out of a total of 44 studied ones had a walking speed value above 0.8 m/s, while upon discharge, there were 29 patients with walking speed above 0.8 m/s. Consequently, it was noticed a walking speed improvement after the treatment of the acute phase of heart failure (p-value=0.1489). Twelve women had a walking speed of less than 0.8 m/s out of the 19 female patients and 9 male patients had a walking speed of less than 0.8 m/s out of the 25 male patients, i.e. p value-0.1384. Everyone else (7 women and 16 men) recorded a walking speed higher than 0.8 m/s.

We assessed the walking speed of heart failure patients in terms of the presence or absence of valvulopathies. We found that out of 30 patients with valvulopathies, 16 recorded a walking speed of less than 0.8 m/s, which represents 53% of the total number of patients. As for the patients with no sympthoms of valvulopathies, only 35% (5 patients out of 14 without valvulopathies) recorded a walking speed < 0.8 m/s (p-value=0.4438). Nineteen patients (representing 54%) recorded a walking speed < 0.8 m/s out of the total number of hypertensive patients. Only 2 patients (representing 22%) had a walking speed < 0.8 m/s, i.e. p-value=0.1791, out of the total number of non-hypertensive patients. Thirteen patients had a walking speed < 0.8 m/s (representing 52%) out of 25 patients with atrial fibrillation. Conversely, only 8 patients out of 19 patients without atrial fibrillation had a low walking speed (representing 42%), i.e. p-value=0.7292. Fourteen patients recorded a walking speed <0.8 m/s (representing 53%) out of 26 patients with heart failure and ischemic heart disease. Analyzing the patients without ischemic heart disease, only 38% had a walking speed <0.8 m/s, p-value= 0.5031. Sixty percents of diabetics had a walking speed < 0.8 m/s and 40% had a walking speed > 0.8 m/s out of 10 patients. In non-diabetic patients, it was found that out of 34 patients, 15 (44.11%) had a walking speed < 0.8 m/s and 19 (55.88%) had a walking speed > 0.8 m/s, p-value =0.6004. In terms of smoking as a risk factor, it was found that only 2 patients out of the total number of smokers had a walking speed < 0.8 m/s. The remaining 11 patients registered a walking speed > 0.8 m/s. Nineteen non-smokers had a walking speed < 0.8 m/s and 12 out of 31 non-smokers had a walking speed > 0.8 m/s, p-value= 0.0143. Among the patients with dyslipidemia, 47.36% had a walking speed <0.8 m/s, while among those without dyslipidemia, the percentage was equal between those with a speed < 0.8 m/s and those with a speed > 0.8 m/s, p-value=1. We analyzed the walking speed of the patients in terms of their age. We found that walking speed decreases in elderly patients, which a perfectly normal matter considering the physical deconditioning and comorbidities associated with elderly patients (p-value=0.1691). We analyzed walking speed in patients with heart failure in terms of the number of days of hospitalization required. The higher the number of hospitalization days required to compensate for the acute phase of heart failure, the lower the patients' walking speed (p-value=0.0348).

We analyzed the biological parameters (hemoglobin, creatinine, ionogram) to see if we can capture an association between the walking speed of heart failure patients and the values of these parameters. Patients with high hemoglobin values recorded a better walking speed than patients with low hemoglobin values (p-value=0.009676, a statistically significant value). Patients with low Na values recorded lower walking speeds compared to those with higher Na values (p-value = 0.01933). Hyposodemia is frequently found in heart failure patients and is clinically characterized by weakness, confusion and physical deconditioning. This explains why we encounter low walking speed values in patients with hyponatremia. In terms of potassium and serum creatinine values, we did not notice a significant relation with the walking speed.

After performing the Walk test, the patients were divided into two groups:

- o patients with walking speed > 0.8 m/s, considered as normal;
- o patients with walking speed < 0.8 m/s considered as low.

It was found that 21 patients recorded a low walking speed in the Walk test and 23 patients recorded a good walking speed out of the total group of 44 heart failure patients studied.

We analyzed the characteristics of both groups from the point of view of risk factors, presence of personal pathological history, clinical, biological, echocardiographic parameters and the drug treatment administered.

It was noticed that 57% were women, 9.5% were smokers, 90.5% were hypertensive patients, 85.7% were dyslipidemic patients, 28.6% were diabetics, 61.9% had a history of atrial fibrillation and 66% had a history of coronary heart disease out of the overall group of patients that recorded a low walking speed.

Also, patients with low walking speed (< 0.8 m/s) had an average age of 71 years (SD 6.266) and an average weight of 72.57 kg (SD 13.457).

Clinically, the patients of this group had an average systolic BP of 116.19 (SD 21,266), ventricular rate of 88.43 beats/ minute (SD 30,498) and oxygen saturation of 94.62% (SD 2,224).

An average value of hemoglobin of 12.106 mg/dl (SD 1.5865), creatinine of 1.2382 mg/dl (SD 0.70965), Na of 136.22 mmol/l (SD 4.989), K of 136.22 mmol/l (SD 4.989) and NT pro BNP of 4138.50 pg/ml (SD 4186.760) was noticed from the biological point of view.

Echocardiographically, low walking speed patients had an average value of right ventricular size of 33.65mm (SD 9.074), left atrium of 43.37mm (SD 7.388), left ventricular systolic diameter (VSTD) of 50.70mm (SD 9.325) and an average value of Tricuspid Annular Plane Systolic Excursion (TAPSE) of 18.4 7mm (SD 3.717). Consequently, the conclusion was that patients with speed < 0.8 m/s had a dilated left atrium and a diminished right ventricular systolic function.

Following the treatment administered to low walking speed patients, we noticed that 76.2% received treatment with furosemide, 47.6% - spironolactone, 28.6% - digitalis, 66.7% - ACEI/ sartans, 28.6% - dual antiplatelet therapy, 81% - beta-blockers and 57.1% - oral anticoagulants.

In terms of patients with heart failure and normal walking speed (V> 0.8 m/s), it was noticed that 30% were women, who were 66.78 years old (SD 12.982) and had an average weight of 87.39 kg (SD 25.464). 47.8% of these patients were smokers, 69.6% were hypertensive, 87% were dyslipidemic, 17.4% had type II diabetes, 65.2% had a history of CHF, 52% had a history of atrial fibrillation and 52.2% had CHD. From a clinical point of view, these patients had an average ventricular rate of 88 beats/ minute (SD 28.049), an average systolic BP of 134.87mmHg (SD 25.742) and an average oxygen saturation of 95% (SD 25.742). Biologically, an average value of hemoglobin of 12.952 mg/dl (SD 1.7699), sodium of 138.35 mmol/l (SD 3.113), potassium of 4.509 mmol/l (SD 0.6653), creatinine of 1.2130 mg/dl (SD 0.50727) and blood glucose of 107.82 mg/dl (SD 27,114) was noticed.

**2.3.2. TUG test**

Upon admission, the average value of the TUG test in the whole group was 16.7193 seconds (SD 5.56735). Upon discharge, the average value of the TUG test of the whole group was 16.7891 seconds (SD 4.87219).

Patients were divided into 2 groups after analysing TUG test value:

- o patients with TUG test duration <15 seconds - expressing preserved mobility;
- o patients with TUG test duration >15 seconds - expressing reduced mobility.

Nineteen patients had a TUG value <15 seconds and 25 patients had a TUG value >15 seconds out of 44 patients studied.

Statistical analysis showed us that the reduced mobility group of patients was composed of 48% women, 28% smokers, 80% hypertensives, 87% dyslipidemics, 24% diabetics and 64% had a history of atrial fibrillation and CHD.

Clinically, patients with a TUG value > 15 seconds, had an average systolic BP of 119.20 mmHg (SD 21,296), a ventricular rate of 85.28 beats/ minute (SD 28,191) and an oxygen saturation of 94.96% (SD 2,300).

From a biological point of view, these patients presented an average value of creatinine of 1.3435 mg/dl (SD 0.71260), hemoglobin of 12.625 mg/dl (SD 1.6819), blood glucose of 115.44 mg/dl (SD 52.041), sodium of 137.52 mmol/l (SD 4.823) and potassium of 4.478 mmol/l. l (SD 0.7090).

Echocardiographically, they had a left ventricular end-diastolic diameter (VSTD) of 52.54 mm (SD 8.959), a left atrium (LA) of 43.22 mm (SD 7.198), a right ventricle (RV) of 35.08 mm (SD 7.587) and a Tricuspid Annular Plane Systolic Excursion (TAPSE) value of 18.29 mm (SD 4,551).

Out of 19 women, 7 had a TUG value lower than 15 seconds. However, the rest of the women recorded a value above 15 seconds. Out of 25 men, 12 had a TUG value lower than 15 seconds and 13 men recorded a value over 15 seconds (p-value= 0.6651).

In our study, 19 valvulopathic patients (representing 63.33%) recorded a TUG test value >15 seconds out of 30 patients, while the group of non-valvulopathic group had only 6 patients (representing 42.85%) with an increased TUG test value (p-value= 0.3419).

Out of 35 hypertensive patients, 20 (representing 57.14%) had a TUG value higher than 15 seconds, and out of 9 normotensive patients, 5 (representing 55%) recorded an increased value of this test (p-value=1).

Out of 25 patients with atrial fibrillation, 16 (representing 64%) had a value higher than 15 seconds in the TUG test, and out of 19 patients without atrial fibrillation, only 9 (representing 47.36%) recorded a value over 15 seconds (p-value=1).

Out of 26 patients with heart failure and CHD, 16 (representing 61.53%) recorded a value over 15 seconds of the TUG test, and out of 18 patients with heart failure but without CHD, 9 patients (representing 50%) had a value higher than 15 seconds (p-value=0.6526).

In terms of the patients with heart failure and diabetes, 6 out of 10 patients (representing 60%) had a TUG test value over 15 seconds, and out of 34 patients with heart failure 19 patients (55.88%) had an increased TUG test value (p-value=1).

Seven (representing 53.84%) out of 13 smokers had a TUG test value over 15 seconds, while 18 out of 31 non-smokers (representing 58.06%) registered a value higher than 15 seconds, with p-value=1.

Out of 38 patients with dyslipidemia, 22 (representing 57.89%) recorded a value over 15 seconds of the TUG test, while the proportion was equal between those with a TUG test over 15 seconds and those with a test below 15 seconds (p-value=1) in patients without dyslipidemia.

### 2.4. Conversations

There are studies that have reported significant associations of walking speed and different cardiovascular risk factors (diabetes mellitus, arterial hypertension, calcifications of coronary vessels as well as the level of C-reactive protein) with the occurrence of cardiovascular events (myocardial infarction, stroke, peripheral arterial disease). These studies have shown that walking speed can be used as a tool in cardiovascular risk stratification in older adults [16].

A Swedish cohort study analyzed 3241 patients over 60 years of age and showed the correlation between the functional capacity of patients with cardiovascular and neuropsychiatric diseases and the risk of morbidity and mortality. Decreased functional capacity was defined as a walking speed of less than 0.8m/s. After 3 years of analysis, it was found that the functional capacity decrease leads to an increased mortality risk in elderly patients with cardiovascular and neuropsychiatric diseases. Thus, walking speed can be a useful and easy-to-use clinical marker for the prognosis of morbidity and mortality in this category of cardiovascular and neuropsychiatric patients [17].

Decreased quality of life is common in patients with cardiovascular diseases and is associated with increased mortality. Association between 6-minute walking speed/ walking distance (6MWD) and patients with cardiovascular disease showed a significant decrease in quality of life in patients with cardiovascular disease and increased mortality [18].

Low walking speed in elderly patients with cardiovascular disease is associated with an increased risk of death. This statement is reinforced by another study that analyzed the correlation between walking speed and causes of death in a group of elderly patients. 3208 patients over 65 years old were enrolled between 1999 and 2001. Walking speed was measured and causes of death were analyzed during the 5-year monitoring period. 209 patients died (99 from cancer and 59 from cardiovascular diseases) out of 3208 enrolled patients. The results of the study showed that there was no correlation between low walking speed and cancer mortality, but there was a correlation between low walking speed and mortality from cardiovascular disease. Thus, low walking speed in the elderly is associated with an increased risk of mortality from cardiovascular diseases [19].

TUG is a test used as a screening tool when assessing the patients' falling risk. It has been proven that TUG test is an increased sensitivity and specificity test used to identify the falling risk in elderly patients [20].

TUG test is a reliable, safe and effective method in assessing functional capacity in patients with heart failure, especially in patients over 60 years. However, TUG has no standard reference values for patients younger than 60 years old. There was a study that analyzed people between 20 and 59 years old using the TUG test. That study looked at the relationship between TUG test results and demographic, physical and mental health risk factors. The study enrolled 200 participants (20 participants per decade). TUG test was performed and information on social-economic status, body mass index, morbidity and mortality index and perception of general physical and mental health was gathered.

Results showed that TUG times were significantly different between decades. Slower times occurred in older compared to younger patients. Higher TUG values appeared in patients with low social-economic status, in people with higher body mass, with comorbidities and poorer physical and mental health. In essence, the study showed that TUG test can be used to monitor physical activity in young people, especially in those with risk factors for physical and mental health [21].

A prospective cohort study performed in 2017-2018, that included patients who subsequently underwent elective surgery on the thoracolumbar spine, showed that TUG pre-surgery assessment of patients was an important predictor of post-surgery adverse events. TUG can be successfully used to identify patients at high risk of post-surgery adverse events during thoracolumbar surgeries [22].

It has been proved that TUG test can be useful in evaluating the functional capacity of patients who are to undergo coronary bypass surgery. Pre- and post-operative patients were evaluated and it was shown that a short-term physical rehabilitation program is useful in improving functional capacity in patients with coronary heart disease who are to undergo coronary bypass surgery [23].

TUG is a test that has been used to measure physical frailty, to monitor the correlation between BP and cardiovascular disease and mortality, especially in younger adults. A linear association was noticed between the increase in systolic and diastolic blood pressure values and the risk of myocardial infarction and stroke [24].

Walking speed measuring tests and TUG test have also proven extremely useful in evaluating functional capacity in patients with ischemic heart disease. They proved that age and biological parameters (creatinine and serum hemoglobin) can influence the mobility of patients with cardiovascular pathologies [25].

A study published in 2020 supports growing evidence that low walking speed is associated with increased hospitalization rates and higher hospitalization costs in patients with cardiovascular disease [26]. Thus, the conclusion was that an improvement of the functional capacity in this category of patients would have a definite benefit on the quality of life also by decreasing the hospitalization rates.

Walking speed and survival in female patients with cardiovascular disease were studied. It was found that the decrease in walking speed is associated with the increase in mortality in female patients with cardiovascular diseases [27]. Improvement in walking speed has led to a decrease in hospitalization and mortality rates among female patients with cardiovascular disease [28].

Walking speed can be used as an important forecasting factor for patients with cardiovascular diseases. However, the population aging phenomenon must be taken into account, because it associates an increased segment of the population with low walking speed. Thus, the maximum walking speed can be an independent predictor for patients with cardiovascular diseases. The assessment of maximum walking speed alongside usual walking speed is useful in forecasting risk stratification for elderly patients with cardiovascular disease [29].

Measuring walking speed over short distances led to the idea that walking speed low value is associated with an increased risk of metabolic syndrome and subclinical atherosclerosis in elderly adults without obvious cardiovascular disease. The coronary arteries were evaluated by emission computed tomography and the carotid arteries - by ultrasound scanning. These studies show that walking speed measuring can be used to highlight the presence of underlying vascular disease [30].

It was found out that patients with a history of myocardial infarction have a lower walking speed than patients without this pathology and they have an increased risk of cardiovascular mortality. The results of the studies show that the assessment and improvement of walking speed are absolutely necessary in the management of physical rehabilitation of patients with myocardial infarction [31]

**2.5. Conclusions**

Further to the study of 44 patients with NYHA class II-III CHF using G-WALK device, it was noticed that patients with lower walking speed (v < 0.8m/s) vs. patients with normal walking speed (v > 0.8 m/s) were older (71.81 years +/- 6.26 vs. 66.78 years +/-12.98, p=0.10), had a lower body weight (72.57 kg +/-13.457 vs. 87.39 kg +/-25.464, p=0.02), a lower blood pressure value (116.1 9 mmHg +/-21.266 vs. 134.87 mmHg +/-25.742, p=0.12), a lower oxygen saturation value (94.62 % +/-2.224 vs. 95.00% +/- 3.205, p=0.647), a lower sodium value (136.22 mmol/l +/-4.989 vs. 138.35 mmol/l +/-3.113, p=0.102) and a higher blood glucose value (115.50 mg/dl +/-54.735 vs. 107.82 mg/dl +/-27.114, p=0.615).

It was also noticed that patients with a higher TUG value (>15 seconds) vs. patients with a normal TUG value (<15 seconds) are older (70.92 years +/-9.729 vs. 66.89 years +/-11.362, p=0.10), have a higher creatinine value (1.3435 mg/dl +/- 0.71260 vs. 1.0618 mg/dl +/- 0.33332, p=0.896) and a higher blood glucose value (115.44 +/-52.041 vs. 106.87 +/-26.686, p=0.615).

After applying the heart failure treatment during the hospitalization period, there was noticed an improvement in the walking speed of the patients, but not an improvement in the TUG value.

Thus, we can conclude that risk factors, such as diabetes, chronic kidney disease, advanced age and heart failure are associated with low mobility and significant physical deconditioning.

Low mobility increases the risk of cardiovascular diseases that consequently increased morbidity and mortality in a long term.

We can thus state that the implementation of rehabilitation programs to increase mobility in patients with heart failure, along with drug treatment and risk factors correction, is essential in reducing morbidity and mortality caused by cardiovascular deseases and in increasing the life quality of patients with heart failure.

# 3. Personal Contributions

Rehabilitation of patients with NYHA class II-III CHF is extremely important because the aging process and the increase in life expectancy have led to an increase in the geriatric population affected by sarcopenia, frailty and deconditioning. Deconditioning, sarcopenia and frailty lead to disability, decrease the quality of life and increase hospital readmission rates and increased mortality.

Rehabilitation programs are developed insignificantly in our country because of the lack of information, low number of specialists, missing protocols and low adherence of patients.

In this work, we have tried to point out the importance of the correct assessment of the functional capacity of patients with NYHA class II-III CHF, because this stage represents the initial point of integrating the patients into rehabilitation programs.

Main objective was to highlight that use of Amadeo robot and G-WALK device provides valuable, fast and reliable information on functional capacity analysis.

Scientific research objectives were to prove that hand grip strength, walking speed and mobility of patients with NYHA class II-III heart failure are influenced by risk factors and associated pathologies:

- men have better hand flexion and extension forces than women;

- patients with valvulopathies show lower values of hand flexion and extension forces compared to those without valvulopathies;

- hypertension negatively influences the hand flexion force;

- atrial fibrillation and CHD are pathologies that can decrease the hand extension and flexion forces;

- type II diabetes did not influence the hand flexion and extension forces;

- walking speed is influenced by the following parameters: age, weight, Na values, blood sugar and oxygen saturation values;

- value of the TUG test is influenced by: age, creatinine and blood sugar.

Technical and economic advantages are:

- simplicity and speed of using these devices in assessing the patients' functional capacity;

- possibility of using this equipment both in the hospital and in outpatient circumstances;

- G-WALK test, TUG test and the measurement of grip strength, using simple protocols, represent a quick and efficient means of assessing frailty, which is an important geriatric syndrome associated with morbidity and mortality rate increase.

Barriers for the study were represented by:

- small number of patients studied;

- lack of long-term follow-up;

- absence of national protocols for the assessment of physical capacity;

- absence of physical rehabilitation centers with a multidisciplinary team.

We believe that the directions the research should be continued in are:

- assessment of a larger number of patients with NYHA class II-III heart failure, but also of patients with other cardiovascular pathologies;

- long-term follow-up and assessment of the quality of life of patients included in physical rehabilitation programs using these devices (Amadeo and G-WALK);

- implementation of national physical rehabilitation protocols for heart failure patients;

- comparing the assessment of patients using classic tests (the 6-minute walking test 6MWT and the cardio-pulmonary exercise test) and the tests used in this work (Amadeo robot and G-WALK device)

**Final considerations**

1. G-WALK devices and Amadeo robot represent simple means of assessing functional capacity.

2. Amadeo robot and G-WALK device can be safely used to evaluate heart failure patients.

3. Walking speed, mobility and grip strength are key components in assessing the functional capacity in elderly patients.

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