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# Functional Assessment of Heart Failure Patients

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**KEYWORDS**

• Functional capacity • Peak oxygen consumption • Six-minute walk test • Muscular strength • Handgrip

**KEY POINTS**

- The gold standard measurement of cardiovascular functional capacity is peak oxygen consumption obtained from a cardiopulmonary exercise test.
- The 6-minute walk test provides an indirect measure of cardiovascular functional capacity.
- Muscular functional capacity is assessed using either a 1-repetition maximum test of the upper and lower body or other methods, such as handgrip measurement.
- The short physical performance battery may provide a helpful, indirect indication of muscular functional capacity.

## INTRODUCTION

Heart failure (HF) is the condition characterized by the inability of the heart to pump sufficient blood to meet the demands of the body. It has been well established that both the prevalence and incidence of HF is increasing.[1] There are 2 primary types of HF, categorized by ejection fraction: Reduced ejection fraction and preserved ejection fraction.[2] Additionally, HF is commonly classified into stages from mild to severe using a symptom-based scale related to functional limitations.

One of the hallmark features of HF is exercise intolerance, which is accompanied by symptoms of fatigue and shortness of breath.[3] As the disease progresses, patients experience a downward spiral as these symptoms typically result in reduced physical activity, which leads to progressively worsening exercise intolerance. Typically, patients with HF are faced with what can be termed a functional disability. Often, their reduced functional abilities restrict or may even prevent them from performing occupational tasks, which may result in loss of work. Additionally, it is well known that patients with HF experience impairment in the ability to carry out activities of daily living and suffer from reduced quality of life.

The objective of this paper was to provide an overview of assessments of functional ability of patients with HF. Two categories of assessment are reviewed: Cardiovascular function and muscular function. The review includes procedural guidance on how to administer the assessments and information related to the advantages and disadvantages of each method. Because both HF types (reduced ejection fraction and preserved ejection fraction) are characterized by exercise intolerance, the procedures can be used effectively with either type of HF.

## CARDIOVASCULAR FUNCTION

The gold standard method for assessing cardiovascular functional capacity is measurement of oxygen consumption ($V\text{O}_2$) during a maximal exercise test. This procedure is known as cardiopulmonary exercise testing (CPX). The principle outcome variable is maximal or peak oxygen $V\text{O}_2$ ($V\text{O}_{2max}$ or $V\text{O}_{2peak}$). Weber and colleagues[4] established a classification system based on peak $V\text{O}_2$

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for patients with HF (**Table 1**). Although exercise testing guidelines have existed for more than 40 years,[5] there is not a uniformly accepted standard for assessing cardiovascular functional capacity in terms of $V_{O_2}$. Review of the scientific and clinical literature reveals that both $V_{O_{2max}}$ and peak $V_{O_2}$ are routinely reported. As reviewed by Arena and colleagues,[6] historically $V_{O_{2max}}$ is used when the measurement methodology includes determination of a plateau in $V_{O_2}$ measurement values during the last 2 work rates of the exercise test. However, not all studies that report the variable in terms of $V_{O_{2max}}$ used that as a criterion and this method is not typically suitable for use with ramp-style protocols. Alternatively, peak $V_{O_2}$ is used when the method determines the highest $V_{O_2}$ value, expressed as milliliters of oxygen per kilogram of body weight per minute (mL $O_2$•$kg^{-1}$•$min^{-1}$) during the exercise test. Another challenge in interpretation is that different studies have used various measurement sampling intervals to determine $V_{O_2}$. A recent scientific statement from the American Heart Association recommends using a rolling average of three 10-s sampling intervals during the exercise test to help standardize this important outcome measurement.[7] For the purposes of this paper, the term peak $V_{O_2}$ is used to indicate cardiovascular functional capacity for patients with HF.

As mentioned, guidelines for exercise testing have been available for more than 40 years. However, in the past 10 years as the evidence base has grown, establishing the clinical importance of CPX measures, there have been a number of scientific statements released.[7–10] Although the focus of this paper is on the assessment of cardiovascular functional capacity, it is important to recognize that CPX is clearly recognized as a valuable component in the diagnosis and prognosis of HF patients. Indeed, the joint report from the European Society of Cardiology/European Association for Cardiovascular Prevention and Rehabilitation and the American Heart Association provides a stratification approach for diagnosis and prognosis of patients with HF.[9] The key CPX measurements, all clearly defined in the report, included in the stratification are the slope of minute ventilation (VE) relative to carbon dioxide production ($V_{CO_2}$; VE/$V_{CO_2}$ slope); peak $V_{O_2}$; exercise oscillatory ventilation; and the change in the partial pressure of carbon. The stratification also includes consideration of the blood pressure and electrocardiographic response during the exercise test, the rate of decline in heart rate after 1 minute of recovery and the reason for test termination.

**Table 1**
**Classification of heart failure patients based on functional status**

| Peak $V_{O_2}$ (mL $O_2$•$kg^{-1}$•$min^{-1}$) | Classification |
|---|---|
| >20 | A. Normal |
| 16–20 | B. Mild to moderate impairment |
| 10–15.9 | C. Moderate to severe impairment |
| <10 | D. Severe impairment |

*Abbreviation:* $V_{O_2}$, oxygen consumption.

*Data from* Weber KT, Janicki JS, Ward DM, et al. Measurement and interpretation of maximal oxygen uptake in patients with chronic cardiac or circulatory failure. J Clin Monit 1987;3:31–7.

### *Assessing Peak Oxygen Consumption from Exercise Tests*

Recent guidelines and scientific statements are available that provide comprehensive recommendations for procedures for clinical exercise testing. A brief overview of some of the important methodologic points is reviewed in this section for obtaining the gold standard assessment of peak $V_{O_2}$.

Exercise testing can be performed with various exercise modes; however, the 2 most common choices are cycle ergometers and treadmills. The advantages and disadvantages to both modes of testing are listed in **Table 2**. There are 2 types of cycle ergometers; Mechanically braked and electrically braked. Work rates on mechanically braked cycle ergometers can be varied by both the rate of pedaling and the resistance to pedaling. This requires a fixed pedal rate of typically 50 or 60 rpm to achieve the desired fixed work rate. Electrically braked cycle ergometers are designed to automatically change the resistance on the pedal as the pedal rate varies to maintain a desired fixed work rate.

Exercise tests are administered according to specified protocols with multiple variations possible. The duration of an exercise test should require at least 6 minutes but no more than 15 minutes, with an ideal time of 10 minutes. The first decision in selecting a protocol is between a fixed incremental or ramp style. A fixed incremental protocol uses a specific work rate either in watts on a cycle ergometer or by a combination of speed and elevation on a treadmill for a set period of time (stage) of 1, 2, or 3 minutes. One of the most desirable features of fixed incremental protocols is that the $V_{O_2}$ of each stage can be estimated (standard error of estimate [SEE] ± 7%) using equations provided by the American College of Sports

**Table 2**
**Advantages and disadvantages of cycle and treadmill modes of exercise testing**

| Mode | Advantages | Disadvantages |
|---|---|---|
| Cycle | Smaller, portable<br>Less expensive<br>Ausculatory blood pressure measurement is easier<br>Electrocardiogram tracings have fewer artifacts | Less familiar activity for patients<br>Leg fatigue may cause early termination<br>Electrically braked ergometers are difficult to calibrate<br>Lack of standardized testing protocols |
| Treadmill | Walking is a more common activity for patients<br>Typically higher peak $V_{O_2}$ values are achieved<br>Work rates can be increased by elevation at a fixed speed | Balance issues, risk of falling<br>Handrail use will impact prediction of peak $V_{O_2}$<br>Blood pressure and electrocardiogram measures are more difficult |

*Abbreviation:* $V_{O_2}$, oxygen consumption.

Medicine.[5] There are many standardized incremental treadmill protocols. The Bruce protocol was commonly used in routine cardiac diagnostic assessments; however, the relatively high first work rate of approximately 5 metabolic equivalents (METs; 1 MET = 3.5 mL $O_2$•kg$^{-1}$•min$^{-1}$) and the large stage increments of 2 to 3 METs makes it unsuitable for patients with HF. Preferred options for this population are either the modified Naughton or a modified Balke protocol. For cycle testing, few standardized protocols exist because the maximal watt level varies directly with the total body weight (muscle mass) of the patient. Certainly, some clinics use a number of standardized incremental protocol options for cycle testing to achieve different expected maximal watt levels. Alternatively, both standardized and individualized ramp-style protocols can be used. Unfortunately, there are no standardized ramp protocols suitable for HF patients. Individualized ramp protocols can be derived using software options with metabolic systems, which require setting a starting and maximal speed of walking (or fixed speed) and an estimate of the functional capacity of the patient in METs. The software then generates the increments in speed and elevation to obtain the estimated MET level in a targeted test time (usually 10 minutes). A similar process is used for cycle testing, setting a starting and expected watt level and then computing the rate of increase in watts to be obtained in a linear fashion over a 10-minute period of time.

Determination of peak $V_{O_2}$ during a CPX requires collecting ventilatory expired gases during the test. The 3 primary variables measured during the test are the total ventilation and the fractional concentrations of expired oxygen and carbon dioxide. As mentioned, additional CPX variables can also be measured, which have prognostic and diagnostic utility. CPX measurements require specialized equipment and trained personnel, which can be a limiting factor, because these resources may not be readily available. However, as more academic programs have developed for training individuals to administer these tests and the costs of the equipment are relatively fixed (ie, the primary cost is the purchase of the equipment, the costs per test are minimal) the opportunities for obtaining a measured peak $V_{O_2}$ are growing.

The next best option for assessing cardiovascular functional capacity is from a maximal exercise test, performed without ventilatory expired gas measurements. This option is commonly available in cardiology clinics and practices. These tests are primarily performed for diagnostic purposes with routine monitoring of the exercise electrocardiogram, along with blood pressure, heart rate, and signs and symptoms. These tests also require specifically trained personnel. Cardiovascular functional capacity can be estimated from either a prediction equation using maximal test time with standardized protocols or from the maximal work rate obtained during the test. With use of any prediction equation, there is some degree of error associated with the estimation. Prediction equations using test time typically have reported error ranges of approximately $\pm$3 to 5 mL $O_2$•kg$^{-1}$•min$^{-1}$. Estimations from maximal work rate are derived using the American College of Sports Medicine equations. However, it is important to recognize that this creates some issues, because these equations were developed for steady-state submaximal work rates (not maximal). Thus, the estimates may result in greater error ranges than those reported for the submaximal level (ie, more than $\pm$7%).

A third option for assessing cardiovascular functional capacity is from a submaximal exercise test. These procedures rely on having a reasonable estimation of maximal heart rate, commonly estimated using age. A heart rate to $V_{O_2}$ (predicted from work rate) relationship is established at 2 submaximal levels and then a linear line is extrapolated to derive an estimated maximal value. Advantages of submaximal testing are that it requires less training from staff, takes less time, and because the patient's effort is submaximal has lower associated risks. However, because many patients with HF are prescribed β-blocker medications,[2] prediction of maximal heart rate is compromised. Thus, this method may not be viable for many patients with HF. A summary of the advantages and disadvantages of 3 exercise testing methods is provided in **Table 3**.

### *Assessing Cardiovascular Functional Capacity Without Exercise Tests*

Exercise testing has inherent limitations (expense [equipment and personnel], time, and risks associated with maximal exercise effort); thus, it is not feasible in all settings. However, because understanding an HF patient's exercise intolerance is important for guiding therapy, alternative methods of assessing cardiovascular functional capacity have been developed.

Field tests for estimating aerobic fitness were originally used with apparently healthy populations and most often involved running 1.5 miles or 12 minutes.[5] Variations of this approach were explored with clinical populations using fixed distance or time while walking. More than 30 years ago, Butland and colleagues[11] reported that walking for 6 minutes may provide useful information in patient populations with functional limitations. Since that time, the 6-minute walk test (6MWT) has gained acceptance in the clinical community as a feasible option to obtain an estimate of cardiovascular functional capacity in disease-based populations known to experience exercise intolerance. Although it is beyond the scope of this paper to provide a thorough review of the clinical uses and limitations of the 6MWT, it is important to recognize that the 6MWT does not accurately predict peak $V_{O_2}$.[12] Some reports have suggested that failure to achieve a certain distance, such as 300 m[13] or 450 m,[14] on the 6MWT has prognostic value. Additionally, some have proposed that measures other than total distance achieved, such as total work performed[15] or heart rate after 1 minute of recovery[16] may provide useful information from the 6MWT. However, there are no well-accepted normative values available to interpret 6MWT results.

The 6MWT is considered simple in concept in terms of the patient directions; however, there are important methodologic requirements. These are briefly reviewed here, with more detailed information available in the guideline statement from the American Thoracic Society (ATS).[17] The first consideration is the location. Ideally, this should be in a semiprivate area free from distractions and potential obstacles. In most clinical settings, this can be done in a hallway that is at least 30 m long. However, it should be mentioned that the length and type (oval vs back-and-forth) may result

**Table 3**
**Advantages and disadvantages of 3 exercise testing methods for assessing cardiovascular functional capacity**

| Mode | Advantages | Disadvantages |
|---|---|---|
| Maximal CPX | Gold standard method<br>Same diagnostic measures from maximal exercise test<br>Additional measures have prognostic value | Expense of equipment<br>Specialized training required for technicians<br>Additional time required for results processing |
| Maximal without CPX | More widely available in clinical settings<br>Less expense (equipment and personnel) | Prediction errors in estimating functional capacity<br>Important prognostic indicators not available |
| Submaximal | Lower risk because test effort is submaximal<br>Less expense (equipment and personnel) | Maximal heart rate predictions not accurate for those on β-blockers<br>Prediction errors in estimating functional capacity |

*Abbreviation:* CPX, cardiopulmonary exercise test.

in slight differences in performance. Attempts to perform this test on a treadmill have not been found to be successful.[18]

Although there are few pretest requirements for the patient, it is important to provide a clear set of instructions pertaining to the objective (walk as far as possible), the requirement to walk, not jog, and the ability to stop and rest if needed. The ATS guidelines provide a brief script that can easily be read before each test. During the test, the amount and type of verbal encouragement should be consistent, because this can influence test performance.[19] The ATS guidelines also provide recommendations for standardizing the communication with the patient during the test.

One of the most important issues with 6MWT administration is a learning effect. The ATS guidelines suggest that "a practice test is not needed in most clinical settings"; however, the guidelines acknowledged that test performance is improved on a second trail. In clinical programs where the 6MWT will be used to influence therapeutic options and in research settings, the validity of the measurement is paramount. Thus, having patients perform at least 1 practice trial is important. Interestingly, Hanson and colleagues[20] reported that 6MWT distance continued to improve over 3 trials (regardless if performed on the same day or over 3 different days) in patients in a cardiac rehabilitation program. Similarly, Wu and colleagues[21] found improvement over 3 consecutive trials both at baseline and after 2 months. In patients with more severe exercise tolerance limitations, such as advanced HF, it was shown that a repeated trial did not result in improvement in 6MWT distance.[22]

Key methodologic considerations for the 6MWT are listed in **Box 1**. The importance of using standardized procedures cannot be overemphasized.

> **Box 1**
> **Important methodologic considerations for the 6-minute walk test**
>
> Standardized location is needed; free from distractions/obstacles; distance between turn around point of ~30 m.
>
> Clear, standardized instructions should be read to the patient before each test.
>
> Clear, standardized feedback should be given to the patient during each test.
>
> Although not required, assessments of heart rate, blood pressure, and rating of perceived exertion are desirable.
>
> To eliminate a learning effect impacting test results, a minimum of 2 trials should be performed (either with a short rest period or on a separate day).

Although the 6MWT is the most commonly used nonexercise test indicator of cardiovascular functional capacity, other assessments have been studied. Some investigators have determined the ability of a shuttle walk test (SWT) to evaluate chronic disease patient populations.[14,23,24] This test requires patients to walk back and forth around 2 markers on a 10-m course (each 10 m = 1 shuttle) at a pace dictated by audio signals recorded on a cassette tape or CD. The speed is initially set at 0.5 m/s and increased by 0.17 m/s every minute. The test is terminated when the patient cannot complete a shuttle in the required time interval. As with the 6MWT, it is recommended that only standardized comments (no encouragement) be provided and that the SWT is repeated at least twice to account for a learning effect.

The major distinguishing characteristic between the 6MWT and SWT is the incremental nature of the SWT. Proponents of the SWT suggest this should result in a greater level of effort, compared with the self-pace nature of the 6MWT, and thus provide a better indicator of cardiovascular functional capacity. Although this test may have merit, to date, the research evidence base is lacking to recommend it be used in place of the 6MWT.

Finally, there have been other attempts to improve on the limitations of the 6MWT by evaluating shorter distances. Studies have investigated the utility of a 100-m walk test in patients with pulmonary disease,[25] 200-m fast walking in patients in cardiac rehabilitation,[26] and a 400-m walk test in patients with HF.[27] All of these tests showed some utility in evaluating patient populations; however, additional research is needed before recommending their use as an assessment of cardiovascular functional capacity.

## MUSCULAR FUNCTION

One of the most frequent misconceptions of HF is that the limitations are solely related to the heart. Evidence has existed for some time that one of significant factors associated with exercise intolerance in patients with HF is skeletal muscle deconditioning.[28] Recent studies have identified mechanisms underlying the weakness observed in the skeletal muscles or patients with HF.[29,30] Thus, is it now well accepted that functional assessments of patients with HF should include measures of muscular performance. In general, tests of muscular performance are not as common as cardiovascular function in healthy adult populations. Even less has been done with disease-based populations to evaluate muscular function.

Thus, the review of muscular function assessments provided herein is primarily based on work with healthy adults. However, the procedures for assessing patients with HF would not vary significantly, only the interpretation of the results.

The gold standard method to assess muscular strength is the 1-repetition maximum test (1-RM). The procedures for this assessment are described in **Box 2**. The resistance for the lifting can be either free weights or resistance exercise machines. Although a 1-RM can be obtained from any weight lifting exercise, the 2 most common lifts are the bench press (for upper body strength) and the leg press (for lower body strength). The American College of Sports Medicine guidelines provide a set of normative values derived from an adult population that was free from chronic disease.[5] Unfortunately, there are no definitive standards for interpreting 1-RM performance in patients with HF. One of the major issues with performing 1-RM assessments is the time requirement, especially if patients need to be familiarized with using the free weights or machines. Other issues are the need for specialized equipment and trained personnel and the risks associated with maximal effort.

**Box 2**
**Important methodologic considerations for the 1 repetition maximum**

To eliminate a learning effect impacting test results, patient should be familiarized with the equipment used for the assessment (ideally on a separate day).

Clear instructions regarding proper breathing (no breath holding) needs to be explained before each test.

A warm up of ~5 repetitions of each movement (bench press or leg press) with no weight is important.

Select a weight that is submaximal (estimated to be ~75% of the patient's capacity) and have the patient complete 1 repetition.

Based on feedback from the patient, select a higher weight that should be able to be lifted 1 time and after a 3-minute rest period attempt 1 repetition. If successful, have the patient attempt 1 more lift of the next highest weight increment. If not successful, lower the weight by 1 increment and have the patient attempt to complete 1 repetition.

Because different muscle groups are involved, both the chest press and leg press tests should be able to be completed at the same testing session.

A second option for performing muscular function assessments is to use a handgrip dynamometer. This test has been used for many years as a physical fitness measure in school-aged children. It does require a handgrip dynamometer; however, these devices are relatively inexpensive (<$400) and are durable. The procedure is simple, only requiring the patient to squeeze the handle of the dynamometer as hard as they can for 3 seconds. After a short rest, the test is repeated 2 more times, with each hand being tested. Although normative values specific for patients with HF do not exist, large population standards are available.[31] These tests are starting to be administered in the HF population and seem to have some merit.[32,33]

There are also indirect measures of muscular strength that can be used as indicators of muscular functional ability. The origins for many of these evaluations came from work with geriatric populations. The method that seems to be gaining the most acceptance is the Short Physical Performance Battery.[34] This functional test includes assessments of gait speed (4 m), strength (sit to stand, repeated 5 times), and balance (standing position). A composite score is formulated, with higher scores indicating better functional ability. A recent study reported that the Short Physical Performance Battery was reduced in patients with HF with preserved ejection fraction compared with age-matched controls and also correlated with total and leg lean mass.[35]

There are other assessments used in geriatric populations that may have utility in assessing the muscular performance of patients with HF. These include both the instrumental activities of daily living[36] and the timed up and go test.[37]

Finally, there are some questionnaire-based methods that have been used in the HF population. Myers and colleagues[38] evaluated the Duke Activity Status Index, the Kansas City Cardiomyopathy Questionnaire, and the Veterans Specific Activity Questionnaire. They compared these questionnaires with results from CPX and the 6MWT in a group of patients with HF. Their findings revealed that these different methods did not correlate well with each other and concluded that they should not be used as surrogate indicators of functional status in this population.

## SUMMARY

Functional assessments of patients with HF provide important clinical information. Cardiovascular functional capacity measures have been utilized for many years. The gold standard method is measuring peak $V_{O_2}$ from a CPX, which has added value by providing measurements with prognostic utility. Peak $V_{O_2}$ can also be estimated from diagnostic maximal exercise tests, commonly used in cardiac care and from submaximal exercise tests. Indirect indicators of cardiovascular functional capacity can also be obtained, the most common of which is the 6MWT. When performed with standardized procedures, the 6MWT can provide useful information when measurements of peak $V_{O_2}$ are not available or are not feasible.

The importance of skeletal muscle as a limiting factor for patients with HF is now well understood. This has led to increased interest in evaluating muscular functional capacity in patients with HF. Efforts are beginning to utilize measures that have been commonly applied to evaluate the muscular fitness of adults, the most common of which are the 1-RM and handgrip. Interpretation of results with normative standards for patients with HF with these 2 assessments is lacking at this time. Work is also beginning to utilize indirect indicators of muscular functional capacity that have been established in geriatric populations. The assessment that may have the most promise for patients with HF is the Short Physical Performance Battery.

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