The use of step tests for the assessment of exercise capacity in healthy subjects and in patients with chronic lung disease*,**

O uso de testes do degrau para a avaliação da capacidade de exercício em indivíduos saudáveis e pacientes com doenças pulmonares crônicas

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Abstract

Step tests are typically used to assess exercise capacity. Given the diversity of step tests, the aim of this review was to describe the protocols that have been used in healthy subjects and in patients with chronic lung disease. Step tests for use in healthy subjects have undergone a number of modifications over the years. In most step tests, the duration is variable (90 s-10 min), but the step height (23.0-50.8 cm) and stepping rate (22.5-35.0 steps/min) remain constant throughout the test. However, the use of a fixed step height and constant stepping rate might not provide adequate work intensity for subjects with different levels of fitness, the workload therefore being above or below individual capacity. Consequently, step test protocols have been modified by introducing changes in step heights and stepping rates during the test. Step tests have been used in patients with chronic lung diseases since the late 1970s. The protocols are quite varied, with adjustments in step height (15-30 cm), pacing (self-paced or externally paced), and test duration (90 s-10 min). However, the diversity of step test protocols and the variety of outcomes studied preclude the determination of the best protocol for use in individuals with chronic lung disease. Shorter protocols with a high stepping rate would seem to be more appropriate for assessing exercise-related oxygen desaturation in chronic lung disease. Symptom-limited testing would be more appropriate for evaluating exercise tolerance. There is a need for studies comparing different step test protocols, in terms of their reliability, validity, and ability to quantify responses to interventions, especially in individuals with lung disease.

Keywords: Pulmonary disease, chronic obstructive; Asthma; Cystic fibrosis; Idiopathic pulmonary fibrosis; Exercise tolerance; Exercise test.

Resumo

Os testes do degrau são utilizados para avaliar a capacidade física. Devido à diversidade desses testes, o objetivo desta revisão foi descrever os protocolos utilizados em indivíduos saudáveis e naqueles com doença pulmonar crônica. Os testes do degrau utilizados em indivíduos saudáveis tiveram várias modificações ao longo dos anos. Na maioria dos testes, a duração é variável (90 s-10 min), mas a altura do degrau (23,0-50,8 cm) e o ritmo (22,5–35,0 degraus/min) permanecem constantes durante todo o teste. Entretanto, a utilização de uma altura fixa e de ritmo constante pode deixar de promover uma intensidade de trabalho adequada para indivíduos com diferentes níveis de aptidão física, e, portanto, a carga de trabalho pode estar acima ou abaixo da capacidade individual. Dessa forma, os protocolos foram modificados com a introdução de mudanças na altura do degrau e no ritmo durante o teste. Desde o final dos anos 70, os testes do degrau têm sido utilizados em pacientes com doenças pulmonares crônicas. Os protocolos são diversificados, com ajustes na altura do degrau (15-30 cm), ritmo (autocadenciado ou externamente cadenciado) e duração (90 s-10 min). Entretanto, a diversidade desses protocolos e a variedade de desfechos estudados impedem a determinação do melhor protocolo a ser utilizado em indivíduos com doenças pulmonares crônicas. Parece que os protocolos mais curtos com elevado ritmo seriam mais adequados para avaliar a dessaturação de oxigênio relacionada ao exercício na doença pulmonar crônica. Testes limitados por sintomas seriam mais apropriados para avaliar a tolerância ao exercício. São necessários estudos comparando diferentes protocolos de teste do degrau em relação a sua reprodutibilidade, validade e habilidade de quantificar respostas a intervenções, especialmente em indivíduos com doença pulmonar.

Descritores: Doença pulmonar obstrutiva crônica; Asma; Fibrose cística; Fibrose pulmonar idiopática; Tolerância ao exercício; Teste de esforço.

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Introduction

The evaluation of exercise capacity can be considered as important as the evaluation of pulmonary function in individuals with chronic lung disease, especially in those who are enrolled in a pulmonary rehabilitation program. Exercise capacity is typically evaluated by maximal or submaximal exercise testing.[1]

Incremental exercise tests that include measurements of gas exchange allow the evaluation of the causes that limit effort and the establishment of training load.[2] In contrast, submaximal exercise tests evaluate exercise tolerance and have a greater sensitivity for detecting changes after interventions, because they are more representative of daily physical activities.[1]

Independent of the choice of testing protocol, whether incremental or constant workload, the use of an ergometer is essential when performing exercise tests. Conventional ergometers include the treadmill and cycle, which are used in order to evaluate exercise capacity. Both have been incorporated into a number of protocols that are well established in the literature.[3-5] A single step can also be used as an ergometer, having the advantage of being readily available for the performance of a very common field test (the step test). Because there is a wide diversity of step test protocols, the aim of this review was to describe the use of step tests for the assessment of exercise capacity in healthy subjects and in patients diagnosed with chronic lung disease.

Step tests employed in healthy subjects

The use of the step as a way to evaluate exercise capacity was first described in the early 20th century. Since then, a variety of step test protocols have been developed.

The Master two-step test

The first step test protocol was described by Master & Oppenheimer in 1929, and this became known as the Master two-step test.[6] The goal was to develop a test that involved a common day-to-day activity and that would have the additional advantage of assessing work with an easily applied method that could be performed in hospitals and physician offices. The original protocol consists of stepping up and down a 2-step platform (each step being 32 cm in height) for a pre-set time of 90 s. The stepping rate is determined from tables based on weight and age. Blood pressure and HR are measured at rest and at 2 min after the end of the test, in order to assess the return to baseline values. Exercise tolerance is evaluated by the time taken for blood pressure to return to the resting value and is considered normal when this occurs within 2 min. Master & Oppenheimer were also the first to express performance on the step test in terms of work (foot-pounds), which is obtained by multiplying the total number of steps climbed by patient weight and by 1.5 (a conversion from inches to feet).[6] Reference values for foot-pounds of work were established by evaluating a sample of 59 male and 56 female healthy individuals between 10 and 74 years of age. Fifteen years later, the Master two-step test was modified. The duration of the test was increased from 90 s to 3 min (a double test). In addition, for the objective detection of latent coronary heart disease, electrocardiography during the test was introduced.[7]

The Harvard pack test

The Harvard pack test (HPT) was developed by Johnson et al. in 1942.[8] The HPT is conducted on a single 40 cm-high step, at a stepping rate of 30 steps/min for 5 min. During testing, subjects must carry a load representing one third of their body weight, which can be placed in a backpack. At that time, the HPT was considered to be one of the most exhausting for the evaluation of exercise capacity. In order to take ethnic differences into account, there were suggestions that certain changes should be made to the HPT, such as a reduction in the stepping rate,[9] the step height,[9,10] the duration of the test[10], and the load to be carried during the test.[10]

The Harvard step test

In 1943, during World War II, one of the most popular exercise tests was introduced: the Harvard step test (HST).[11] The HST was developed by professors at Harvard University as a means of assessing the aerobic capacity of young athletes attending that university.[11] The test is performed on a single 50.8 cm-high step, the stepping rate is paced by a metronome at a stepping rate of 30 steps/min, and the duration is 5 min.

The HST was adapted for use in adolescents by Gallagher & Brouha.[12] The adaptations involved changes in the duration of the test, which was reduced to 4 min, and the height of the step was set at one of two levels (45 cm or 50 cm), according to the body surface of the adolescents (< 1.85 m^2 and ≥ 1.85 m^2, respectively). Exercise capacity, estimated from the duration of the test and of the return to the resting HR, was similar in both groups. These data suggested that the height of the step should be adjusted according to the body surface, given that a similar level of work was observed. All adolescents (n = 154) were able to complete the full 4 min of the test without showing extreme fatigue.

The Astrand-Ryhming step test

The Astrand-Ryhming step test[13] is a further variation on the HST. In its original version, first described in 1954, the duration of the test was 6 min, with a stepping rate of 22.5 steps/min. For the first time, different step heights were recommended for the evaluation of men and women (40 cm and 33 cm, respectively). In 1960, the Astrand-Ryhming step test was modified to reduce its duration to 5 min,[14] although the step height and stepping rate were not changed.

Gradational step tests

Until the mid-1960s, every step test protocol, with the exception of that for the Master two-step test, used a fixed step height and stepping rate throughout the test. That began to be viewed as a disadvantage, because the fixed height and constant stepping rate could result in inadequate work intensity, as well as a workload above or below individual capacity, for subjects with different levels of fitness.[15] Consequently, Nagle et al.[15] developed a test known as the 4-box step, which consisted of four steps of varying heights (10, 20, 30 and 40 cm). Initially, subjects performed the test at a constant stepping rate of 30 steps/min, for 3 min at each step height. The test was interrupted if any of the following occurred: the subject was unable to maintain the pace; there was a fall in systolic blood pressure when the HR was near the maximum (typically 180 bpm); the HR was ≥ 168 bpm and there were signs that the subject would not be able to make the necessary adjustments in order to advance to the next step. Most subjects were unable to start the third step height (30 cm). The stepping rate was then reduced to 24 steps/min in an attempt to allow subjects to complete the entire test. However, this reduced stepping rate resulted in an inadequate workload for well-conditioned subjects. Therefore, those same authors created a gradational step test in which a crank or electric motor could be used in order to provide gradual increases in the step height (from 2 cm to 50 cm) during the test.[16] The initial step height was chosen based on the general health status of the subject. Various combinations of stepping rate and step height increases were tested, and the energy demands for each were compared with those for the standard treadmill test. The combination of a stepping rate of 30 steps/min and 2-cm increases in step height was determined to be similar to treadmill walking in terms of the physiological effects produced.

In the late 1960s, Kurucz et al.[17] described a test that combined increases in step height with increases in the stepping rate. The Kurucz et al. test is composed of three stages, each lasting 5 min. It starts at a stepping rate of 24 steps/min on a 38-cm step, then the stepping rate is increased to 30 steps/min with no change in step height, and the step height is increased to 50.8 cm with no change in the stepping rate. The test is stopped when the HR reaches 150 bpm.

The Queen's College step test

In 1972, McArdle et al.[18] developed the Queen's College step test, the aim of which is similar to that of the HST (to estimate the aerobic capacity of university students). The Queen's College step test was initially described as being performed on the bleachers of the university gymnasium (step height, 41.3 cm), because this allowed simultaneous testing of a large number of students. The test had a duration of 3 min and featured different stepping rates for women and men (22 and 24 steps/min, respectively).

The Memorial Hospital step test

In 1985, Siconolfi et al.[19] proposed a modified step test in which the height of the step was fixed (at 25.4 cm) and there were three stages, each lasting 3 min, at stepping rates of 17, 26, and 34 steps/min.

The Chester step test

Another step test with an incremental pattern is the Chester step test (CST), developed in 1995 by Sykes[20] in order to assess aerobic capacity and to predict the maximal aerobic power of firefighters. Although the test can be performed using any one of four step heights (15, 20, 25, or 30 cm), the step height must remain fixed throughout the test. The test duration is 10 min (in five 2-min stages). The test is paced with a metronome, starting at a stepping rate of 15 steps/min and increasing by five steps every 2 min (15, 20, 25, 30, and 35 steps/min, respectively, in each of the five stages).

Comparisons among step tests employed in healthy subjects

A summary of various step test protocols is shown in Table 1. In all of the studies cited in the table, step tests were used in order to assess exercise capacity in healthy subjects.

Step tests employed in subjects with chronic lung disease

To date, few studies have used step tests for evaluation of individuals with chronic lung disease. Such tests can be useful for determining the exercise capacity of patients with various types of lung disease.

Asthma

In the first study to use a step test in individuals with asthma, the Master two-step test was employed as a way to induce bronchospasm for estimating the effects that treatment with a beta-blocker (practolol, one 50-mg tablet four times a day for three days) has on the response to exercise in a group of adult asthma patients (38-54 years of age).[21] The step test did not induce bronchoconstriction, leading to

Table 1 - Characteristics of the protocols used in healthy subjects.

Study	Protocol characteristics			
	Step height/cm	Steps/min	Duration/min	Pacing
Master & Oppenheimer[6]	23.0	a	1.5	SP
Master et al.[7]	23.0	30.0	3.0	SP
Johnson et al.[8]	40.0	30.0	5.0	EP
Brouha et al.[11]	50.8	30.0	5.0	EP
Gallagher & Brouha[12]	50.8	30.0	4.0	EP
Rhyming[13]	40.0 (men) 33.0 (women)	22.5	6.0	EP
Astrand[14]	40.0 (men) 33.0 (women)	22.5	5.0	EP
Nagle et al.[15]	10, 20, 30, and 40	30.0	3.0	EP
Nagle et al.[16]	2.0-50.0	30.0	20.0	EP
Kurucz et al.[17]	38.0	24.0	5.0	EP
	38.0	30.0	5.0	EP
	50.8	30.0	5.0	EP
McArdle et al.[18]	41.3	24.0 (men) 22.0 (women)	3.0	EP
Siconolfi et al.[19]	25.4	17.0	3.0	EP
		26.0	3.0	EP
		34.0	3.0	EP
Sykes[20]	15.0, 20.0, 25.0, or 30.0	15.0	2.0	EP
		20.0	2.0	EP
		25.0	2.0	EP
		30.0	2.0	EP
		35.0	2.0	EP

SP: self-paced; and EP: externally paced. [a]As fast as possible, to be performed in 90 s.

speculation that the exercise intensity at the peak of exercise did not produce an adequate level of stress. Step tests were later used in assessing exercise-induced bronchospasm (EIB) in school-age children with asthma.[22-24] In a study of elementary school children suspected of having exercise-induced asthma, Feinstein et al.[23] employed a single step with a height of 15-20 cm, the step height chosen according to the height and baseline exercise capacity of the child, and a test duration of 5 min, with a stepping rate sufficient to maintain the HR at 150-200 bpm throughout the test. Of the 26 children who presented EIB, as evaluated by the step test, 23 were subsequently diagnosed with asthma. The authors concluded that this protocol could be used to identify children with suspected but undiagnosed asthma. Tancredi et al.[25] compared the step test and the treadmill exercise test in terms of the fall in FEV_1 in children with asthma. The step test protocol consisted of a single step (30 cm high) and a stepping rate of 30 steps/min for 3 min. The fall in FEV_1 was greater after the treadmill exercise test than after the step test (15.0 ± 7.5% vs. 11.7 ± 5.9%). It is noteworthy that the total duration of the treadmill exercise test was longer than was that of the step test (6-8 min vs. 3 min). In addition, the treadmill exercise test was continued for an additional 4 min after the children had reached 80% of their maximum predicted HR. The authors did not report the HR values during the step test, precluding any comparison between the step test and the treadmill exercise test in terms of the level of exertion at the 3-min mark. However, the authors concluded that, although the treadmill exercise test induced a greater fall in FEV_1, the step test is a useful alternative, because it is a rapid, inexpensive, and reproducible means of detecting EIB.

From our point of view, the step test is a reasonable alternative for detecting exercise-induced asthma when the protocol of choice induces an exercise intensity of 80% of the maximal HR of the individual, maintained for at least 5 min. However, there is a need for studies comparing this specific step test protocol with tests conventionally used to detect EIB (e.g., methacholine challenge, the treadmill exercise test, and the cycle ergometer test).

Cystic fibrosis

Studies in patients with cystic fibrosis (CF) have employed a step test performed on a single-step (15 cm high), at a stepping rate of 30 steps/min, for 3 min.[26-28] In one such study, Balfour-Lynn et al.[26] compared the step test with the six-minute walk test (6MWT) in a sample of 54 pediatric CF patients with a mean age of 12.5 years (range, 6-17 years) and a mean FEV_1 (% of predicted) of 64% (range, 14-103%). The authors found that the step test induced greater dyspnea and a higher HR than did the 6MWT, although the post-exercise reduction in SpO_2 was comparable between the two types of tests. In a subgroup of those patients (n = 12), the authors also analyzed the reproducibility of the step test. Between two step tests, performed on different days, a difference in the stepping rate was observed in only 1 patient (difference, 5 steps). A similar study was conducted by Aurora et al.,[27] although the sample consisted of children with extremely poor lung function (mean FEV_1, 34% of predicted) who were candidates for lung transplantation. In those patients, the mean increase in HR (over baseline) was significantly greater during the step test than during the 6MWT (30% vs. 18%), as was the fall in SpO_2 (4% vs. 2%). Narang et al.[28] compared a 3-min step test with a symptom-limited cycle ergometer test in children with CF (FEV_1 > 50% of predicted), evaluating HR, dyspnea, and SpO_2. The post-exercise increase in HR was significantly higher for cycling than for stepping (78 bpm vs. 46 bpm). The incidence of dyspnea, as assessed by a visual analog scale, was also higher for cycling (51 mm vs. 42 mm). Although there were no statistically significant differences between the two types of tests in terms of the post-test SpO_2, three patients showed significant oxygen desaturation (> 4%) during the cycle ergometer test, no such desaturation having been observed during the step test. Therefore, the authors concluded that, although the step test is simpler and easier to use, the cycle ergometer test is preferable because it provides more information. Although the authors posited various hypotheses to explain why those three patients had significant oxygen desaturation only during the cycle ergometer test, the difference in exercise duration between the protocols does not appear to have been considered. The desaturation occurred, on average, after 8 min of cycling and therefore could not have been observed in the 3-min step test.

For patients with CF, the choice of protocol should take into account the severity of the disease. In patients who are more severely affected, a 3-min step test seems appropriate for assessing exercise-induced oxygen desaturation and could be an alternative field test when sophisticated exercise testing is not available. In patients with mild lung impairment, the protocols of the step test should be either incremental or longer, i.e. symptom-limited, in order to achieve an intensity that is sufficient to evaluate cardiopulmonary stress and exercise tolerance.

Idiopathic pulmonary fibrosis

The protocols of step tests used in the assessment of patients with idiopathic pulmonary fibrosis (IPF) differ among studies.

Dal Corso et al.[29] tested the reproducibility of a 6-min step test in patients with IPF, as well as testing the validity of the test by contrasting metabolic and cardiopulmonary responses with those elicited by a maximal exercise test performed on a cycle ergometer. A step height of 20 cm was used, and the test was self-paced, as is the 6MWT. The test was highly reproducible, the mean difference in stepping rate between the two tests being 1.3 ± 2 steps/min; similarly, HR, maximal oxygen consumption (VO_{2max}), and SpO_2 did not differ by more than ± 5 bpm, ± 50 mL, and ± 2%, respectively. The VO_{2max} achieved during the step test was 90% of that obtained during the cycle ergometer test. The mean SpO_2 observed during the cycle ergometer test (88.7% ± 4.8) was comparable to that observed during the 6-min step test (87.3% ± 4.2). However, 4 of the 31 patients showed oxygen desaturation only during the step test and not during the cycle ergometer test.

In a longitudinal study, Stephan et al.[30] correlated oxygen desaturation during the step test with survival in patients with IPF. The test involved a step height of 20 cm, was self-paced, and had a duration of 4 min. An $SpO_2 \leq 89\%$ was found to be a strong predictor of mortality in this population.

In a study conducted by Rusanov et al.,[31] the protocol consisted of stepping up and down as quickly as possible, fifteen times, on a 20 cm-high step. The mean time to perform the test was 52 ± 12 s. The degree of oxygen desaturation observed during the step test was found to be a predictor of the VO_{2max} measured on a cycle ergometer test. The same authors recently showed that the degree of oxygen desaturation obtained with this step test protocol is also a predictor of mortality in patients with IPF.[32]

The predominant factor limiting the exercise capacity of patients with IPF is circulatory impairment. Therefore, it would be reasonable to use shorter protocols when the primary outcome to be evaluated is oxygen desaturation. However, symptom-limited protocols should be tested in order to provide clinically relevant longitudinal information.

COPD

Few studies have described the use of step tests in individuals with COPD. Swinburn et al.[33] were the first to use a step test in a sample of patients with COPD (mean FEV_1, 0.8 ± 0.3 L). In that study, the authors compared the 6MWT, a step test, and a cycle ergometer test. The step test was performed on a platform (25 cm high), at a stepping rate of 15 steps/min, for 10 min. The VO_{2max} and ventilation values were higher for the step test than for the 6MWT and the cycle ergometer test.

Two studies described a protocol involving a step test in which patients were instructed to step up and down 15 times, on a 25-cm step, as quickly as possible.[34,35] A study conducted by Kramer et al.[34] showed a negative correlation between SpO_2 and disease severity. In a study conducted by Starobin et al.,[35] the SpO_2 observed during a step test was not found to correlate with the VO_{2max} observed during an incremental cardiopulmonary exercise test or with the distance walked on the 6MWT.[35]

Various studies conducted in Brazil have compared step tests with the 6MWT, therefore employing 6-min, self-paced step tests.[36-39] Those studies demonstrated that both tests induce equivalent cardiorespiratory stress and similar SpO_2.

Because of its incremental profile, the CST has recently come to be used in patients with COPD. However, in a study conducted by de Camargo et al.,[40] only 7 of the 32 patients evaluated were able to complete even three of the five stages of the test. The authors speculated that the combination of the initial stepping rate (15 steps/min) and the increases in that rate (by 5 steps every 2 min) make the CST a difficult test for COPD patients to perform. Therefore, a modified version of the CST should be developed for these patients. In this context, a promising step test has been described for patients with COPD.[41] In brief, it is an externally paced test with an incremental profile. The initial stepping rate is 10 steps/min, increasing by 1 step/min every 30 s, until patient tolerance has been reached. Data from a pilot study involving 12 patients with COPD (mean FEV_1, 53.3 ± 16.4% of predicted) show that the protocol elicits maximal cardiopulmonary and metabolic responses that are similar to those observed during an incremental cycle ergometer test, and the new test is well tolerated and reproducible in patients with COPD.

Among the field tests used to assess exercise capacity in patients with COPD, the step test stands out by virtue of its portability. Therefore, step tests could be used in first-line screening for COPD. Outcomes obtained from a step test (number of steps taken, degree of oxygen desaturation, time to oxygen desaturation, and estimated amount of work performed) could be compared with other conventional markers of COPD severity.

Table 2 - Characteristics of the protocols used in patients with chronic lung diseases.

Study	Disease (n)	Protocol characteristic			
		Step height/cm	Steps/min [total steps]	Duration/min	Pacing
Nicolaescu et al.[21]	Asthma (10)	23	[a]	1.5	SP
Young et al.[22]	Asthma (32)	15-20[b]	-	5.0	SP
Feinstein et al.[23]	Asthma (548)	15-20[b]	-	5.0	SP
Feinstein et al.[24]	Asthma (48)	15-20[b]	-	5.0	SP
Tancredi et al.[25]	Asthma (154)	30	30	3.0	EP
Balfour-Lynn et al.[26]	CF (54)	15	30	3.0	EP
Aurora et al.[27]	CF (28)	15	30	3.0	EP
Narang et al.[28]	CF (19)	15	30	3.0	EP
Dal Corso et al.[29]	IPF (31)	20	-	6.0	SP
Stephan et al.[30]	IPF (59)	20	-	4.0	SP
Rusanov et al.[31]	IPF (51)	20	[15]	[a]	SP
Shirit et al.[32]	IPF (51)	20	[15]	[a]	SP
Swinburn et al.[33]	COPD (17)	25	15	10.0	EP
Kramer et al.[34]	COPD (96)	25	[15]	[a]	SP
Starobin et al.[35]	COPD (50)	20	[15]	[a]	SP
de Camargo et al.[40]	COPD (32)	20	15 with a 5-step increase every 2 min	10.0	EP
Dal Corso et al.[41]	COPD (12)	20	10 with a 1-step increase every 30 s	[c]	EP

SP: self-paced; EP: externally paced; CF: Cystic fibrosis; and IPF: idiopathic pulmonary fibrosis. [a]As fast as possible, according to the pace of the patient. [b]Based on physical fitness and height of the child. [c]Symptom-limited.

Comparisons among step tests employed in subjects with lung disease

A summary of various step test protocols can be seen in Table 2. In all of the studies cited in the table, step tests were used in order to assess exercise capacity in subjects with lung disease.

Conclusion

In our review of the literature, we found that step tests, whether used in healthy subjects or in patients with lung disease, can be classified as self-paced[21,23,29-32,34-39] or externally paced.[25,26,33] The main disadvantage of self-paced tests is that performance can vary depending on the level of patient motivation. Another disadvantage is that such tests are limited by time. However, an externally paced test has the advantage of comparing cardiopulmonary responses under similar workloads,[41] which is not possible in self-paced tests, because the variability in the number of steps climbed changes the amount of work performed. Therefore, comparisons between pre- and post-intervention values are not possible.

The protocols described in the literature showed specific outcomes (number of steps, VO_{2max}, degree of oxygen desaturation, fall in FEV_1, etc.) for each disease. In addition, the diversity of protocols precluded the determination of which step test protocol is the best for application in patients with chronic lung disease. However, the assumption that a step test could be considered a maximal or a submaximal exercise test seems reasonable when step height and stepping rate are increased or maintained, respectively, throughout the test. Tests in which a constant stepping rate is maintained throughout the test might be considered maximal exercise tests depending on the degree of cardiopulmonary stress that results from the step height and stepping rate, relative to the previous aerobic capacity and to the underlying lung disease. Shorter protocols with a high stepping rate seem to be more appropriate for assessing exercise-related oxygen desaturation in chronic lung disease.

Studies measuring gas exchange parameters during step tests with incremental or constant protocols should be performed in order to compare such tests with the gold standard assessment (incremental and constant cycle ergometer tests), in terms of the cardiopulmonary responses obtained. In addition, research comparing different step test protocols, in terms of their reproducibility and ability to quantify responses to interventions, should be conducted, especially in patients with lung disease.

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