Development of a shuttle walking test of disability in patients with chronic airways obstruction

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Abstract

Background **The aim was to develop a standardised and externally paced field walking test, incorporating an incremental and progressive structure, to assess functional capacity in patients with chronic airways obstruction.**

Methods **The usefulness of two different shuttle walking test protocols was examined in two separate groups of patients. The initial 10 level protocol (group A, n = 10) and a subsequent, modified, 12 level protocol (group B, n = 10) differed in the number of increments and in the speeds of walking. Patients performed three shuttle walking tests one week apart. Then the performance of patients (group C, n = 15) in the six minute walking test was compared with that in the second (modified) shuttle walking test protocol. Heart rate was recorded during all the exercise tests with a short range telemetry device.**

Results **The 12 level modified protocol provided a measure of functional capacity in patients with a wide range of disability and was reproducible after just one practice walk; the mean difference between trial 2 *v* 3 was −2·0 (95% CI −21·9 to 17·9) m.**

There was a significant relation between the distance walked in the six minute walking test and the shuttle walking test (rho = 0·68) but the six minute walking test appeared to overestimate the extent of disability in some patients. The shuttle test provoked a graded cardiovascular response not evident in the six minute test. Moreover, the maximal heart rates attained were significantly higher for the shuttle walking test than for the six minute test.

Conclusions **The shuttle walking test constitutes a standardised incremental field walking test that provokes a symptom limited maximal performance. It provides an objective measurement of disability and allows direct comparison of patients' performance.**

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Objective measures of disability are important for the assessment and clinical management of patients with chronic airways obstruction. As laboratory assessment is not widely available and may be expensive and intimidating to the patient, field tests of walking ability are often used. These usually comprise a self paced test in which the patient walks as far as possible in either six or twelve minutes.[1,2] Although attractive, these protocols are difficult to standardise and may be influenced by motivation and encouragement.[3] In addition, their very simplicity limits the information that can be obtained from them about the physiological and symptomatic changes that occur during exercise.[4] The purpose of this study was to develop a simple, standardised test of disability that overcomes these limitations to determine functional capacity in patients with chronic airways obstruction.

Exercise tests based on a single work rate may add little to the studies performed at rest.[5] The proposed test therefore is incremental and progressive, stressing the individual to a symptom limited maximal performance. The protocol was modified from that of a progressive, externally paced 20 metre shuttle running test, widely used as a field test of functional capacity in athletes.[6] Our test requires the patient to walk up and down a 10 m course, with the walking speed dictated by a prerecorded audio signal played on a cassette recorder. In the first instance a downgraded 10 level protocol was used, the speed of walking being proportional to the speeds of running used in the Léger and Lambert shuttle test. Evaluation of the performance of a group of patients using this protocol led to the development of a modified, 12 level protocol. This used a greater range of walking speeds to accommodate patients with minimal disability as well as those more severely disabled.

This paper, firstly, examines the feasibility and reproducibility of shuttle walking test protocols and, secondly, compares patients' performance in the modified (second) shuttle walking test with that in the standard six minute walking test.

Methods

PATIENTS

The patients were recruited from medical clinics and given a full explanation before informed consent was obtained. Patients known to be hypoxic with cor pulmonale or ischaemic heart disease were excluded, as were subjects with neurological or locomotor disorders. Patients had no alteration made to their medication during the study.

Three groups of patients were recruited on the basis of convenience. Groups A (n = 10)

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Table 1 Physical characteristics of the three groups of patients

Group	n (M:F)	Age (y): mean (range)	FEV_1 (l)$_{BPTS}$
A	10 (9:1)	64 (54–73)	0·50 (0·36–1·45)
B	10 (6:4)	63 (52–74)	1·10 (0·60–2·10)
C	15 (10:5)	64 (45–71)	1·20 (0·50–2·85)

and B (n = 10) participated in the reproducibility studies of the downgraded and modified shuttle walking protocols respectively, and group C (n = 15) was recruited for the comparison of the shuttle walking test with the six minute walking test. Table 1 shows the physical characteristics of the three groups.

The study was approved by the local ethical committee.

EXERCISE TEST PROCEDURES

Shuttle walking test

The shuttle walking test required the patient to walk up and down a 10 m course. The course was identified by two cones inset 0·5 m from either end to avoid the need for abrupt changes in direction (fig 1). The speed at which the patient walked was dictated by an audio signal played on a tape cassette, originally generated from a BBC microcomputer. The accuracy of the timed signal was ensured by the inclusion on the tape of a calibration period of one minute.

Figure 1 Diagram of the shuttle walk

The explanation to the patient was standardised and played from the tape before the start of the test. The patient was advised: "Walk at a steady pace, aiming to turn around when you hear the signal. You should continue to walk until you feel that you are unable to maintain the required speed without becoming unduly breathless."

The start of the test was indicated by a triple bleep. Thereafter the tape emitted a single bleep at regular intervals, at which point the subject attempted to be at the opposite end of the course—that is, by the time the patient heard the signal he should be turning round the cone to proceed back down the course. Each minute the speed of walking was increased by a small increment. For example, in the modified protocol the increase was 0·17 m/s each minute, so the patient was required to walk progressively faster. A change of speed to the next level was indicated by a triple bleep from the tape recorder.

The first speed of walking was referred to as level 1, the second as level 2, and so on. Each level lasted for one minute and the tape continued for 10 levels in the downgraded protocol and for 12 in the modified protocol. The number of shuttles (10 m lengths) in each level was dictated by the walking speed at that level (table 2). For example, the modified shuttle walking test protocol required the patient to complete three shuttles in the first level. The number of shuttles the patient was required to complete within consecutive levels increased by one—that is, for level 2 four shuttles, for level 3 five shuttles, and so on. Figure 2 shows the total number of shuttles completed at the end of each level. To help the patient to establish the routine of the test and the first, very slow, speed of walking, the operator walked alongside for the first minute. The patient had 20 seconds to complete each of the three shuttles in the first minute. After this first minute patients paced themselves to coordinate their walking speed with the timed signals. When patients reached the cone before the signal, they were instructed to remain until the signal indicated that they could proceed with the test. The operator sat alongside the 10 m course and no encouragement was given. The only verbal contact was the advice given each minute to increase the walking speed slightly. All patients found it easy to pace themselves and no difficulties were encountered in administering the test.

The end of the test was determined by either (*a*) the patient, when he or she was too breathless to maintain the required speed or (*b*) the operator, if the patient failed to complete a shuttle in the time allowed (that is, was more than 0·5 m away from the cone when the bleep sounded) or (*c*) attainment of 85% of the predicted maximal heart rate derived from the formula [210 − (0·65 × age)].

Downgraded shuttle walking test The initial study used a protocol for which the timings of the speeds and signals were simply downgraded from the speeds used by Léger and Lambert in the 20 metre shuttle running test.[6] The starting speed was 0·62 m/s and the test continued for a maximum of 10 levels—that is, for 10 minutes. The increase per level was 0·10 m/s, resulting in a final speed of 1·52 m/s (3·4 mph) (table 2). If the patients were capable they completed nine shuttles (90 m) in the last minute of the test. This protocol was examined with the patients in group A.

Modified shuttle walking test After analysis of the results of the downgraded protocol a modified shuttle walking protocol was adopted. The timings of the signals for this protocol were modified from the 10 level protocol described above—specifically there was a slower start (0·50 m/s) than in the downgraded protocol but the increments of 0·17 m/s each minute were slightly greater. The timed signals for this modified protocol continued for 12 minutes, the final speed (level 12) being 2·37 m/s (5·3 mph) (table 2). If the patients were

Table 2 The shuttle walk protocols

	Downgraded protocol			Modified protocol		
	Speed			Speed		
Level	m/s	mph	No of shuttles per level	m/s	mph	No of shuttles per level
1	0·62	1·39	3	0·50	1·12	3
2	0·72	1·61	4	0·67	1·50	4
3	0·82	1·83	4	0·84	1·88	5
4	0·92	2·06	5	1·01	2·26	6
5	1·02	2·28	6	1·18	2·64	7
6	1·12	2·51	6	1·35	3·02	8
7	1·22	2·73	7	1·52	3·40	9
8	1·32	2·95	7	1·69	3·78	10
9	1·42	3·18	8	1·86	4·16	11
10	1·52	3·40	9	2·03	4·54	12
11				2·20	4·92	13
12				2·37	5·30	14

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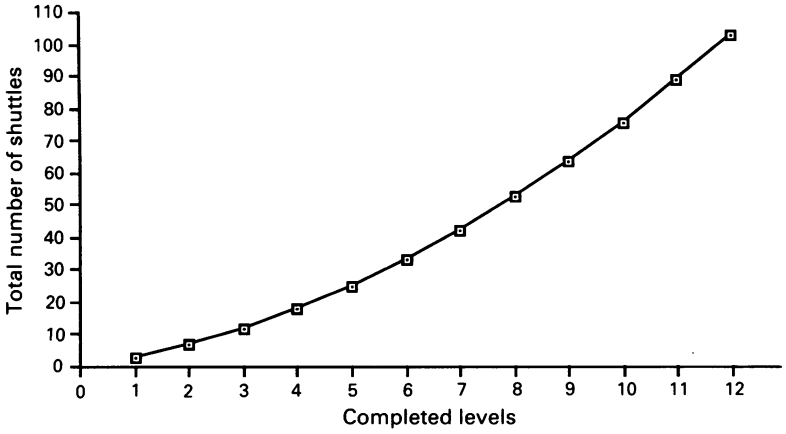

Figure 2 Cumulative number of shuttles (10 m lengths) completed at the end of each level (modified protocol).

capable of reaching this speed they would complete 14 shuttles (140 m) in the final minute. This protocol was examined in a separate group of patients, group B.

Reproducibility of the shuttle walking test The procedure adopted for examining the reproducibility of both the downgraded and the modified protocol was the same. Patients made three visits to the hospital, at intervals of one week and at the same time of day. They received no bronchodilators for three hours before the test, but took all other medicines as usual. The baseline measurements at each visit included spirometry (FEV_1 and FVC), the Borg breathlessness scale,[7] heart rate, and completion of the Chronic Respiratory Disease Questionnaire.[8] Heart rate was monitored throughout the exercise by a short range telemetry device (Polar Electro Sports Tester PE3000). Reproducibility was examined by comparing the distances recorded for each of the three trials.

Six minute walking test

The six minute walking test was conducted along a 45 m hospital corridor. The operator sat half way along the corridor in a visible position, issuing standardised instructions and encouragement—either "You're doing well" or "Keep up the good work"—as the patient passed.[3]

Comparison of the shuttle and the six minute walking tests

Fifteen patients consented to take part in the comparison of the two tests (group C). The protocol for the modified shuttle walk was used for this study. The reproducibility study showed that only one practice of this shuttle test was necessary.

Two practice six minute walks were performed to counteract any learning or training effect.[3,9] The result of the third trial was used in the analysis. Three visits were required, with the same baseline measurements as before. Visit 1 comprised two six minute walking tests and one shuttle walking test, with at least 45 minutes' rest between each exercise test. For visits 2 and 3 a randomised balanced design was used, with one shuttle walking test followed one week later by a six minute walking test or vice versa.

Table 3 Reproducibility studies on the shuttle walking test

	Downgraded protocol (group A)			*Modified protocol (group B)*		
Trial	*r*	*d (m)*	*(95% CI(m))*	*r*	*d (m)*	*(95% CI (m))*
1 *v* 2	0·95	0	(−38·8 to 38·8)	0·98	−31	(−49·0 to 13·0)
1 *v* 3	0·94	−13	(−28·0 to 6·0)	0·99	−33	(−48·1 to 17·9)
2 *v* 3	0·99	−11	(−53·0 to 31·6)	0·98	−2	(−21·9 to 17·9)

STATISTICAL ANALYSIS

Statistical analysis was carried out according to the recommendations of Bland and Altman,[10] with the CIA software package V1·1 and the Minitab V7·0 statistical package for IBM compatibile computers to assess the agreement between the tests. Relationships between performance in the three trials of groups A and B were evaluated by means of the Pearson product moment coefficient. Relationships between performance and Borg scores in the shuttle test and the six minute walking test were evaluated by using Spearman's rho (ρ). A 5% level of significance was used throughout.

Results

There was no significant difference in the scoring of the four components of the Chronic Respiratory Disease Questionnaire between the three separate visits for groups A, B, or C. All the patients were clinically stable throughout the trial (FEV_1 values remained similar within each group). The patients were therefore both physically and psychologically stable during the study.

No patients were excluded or withdrew from the study of either the downgraded or the modified protocol. The patients did not find it difficult to pace themselves correctly. Nor was any patient "disqualified" because the speed of walking was misjudged. The agreement between trials was examined in two different ways. The starting point was to examine the relationships between distances walked in trials 1, 2, and 3. In addition, the agreement between the results of the three trials was examined on the basis of the mean difference (d) and the 95% (CI) for this bias[10] (table 3).

REPRODUCIBILITY STUDIES

Downgraded shuttle walking protocol (group A)

The distance walked ranged from 20 to 510 m—that is, the end of the 10 level protocol—with a mean distance of 211, 211, and 222 m for trials 1, 2 and 3 (fig 3A). There was no significant difference in performance between trials. The relationship between performance in the three trials was strong (table 3). The mean maximal heart rate attained was 114, 111, and 111 beats/min for trials 1, 2, and 3 respectively (fig 3B).

Modified shuttle walking protocol (group B)

Distances walked ranged from 90 to 520 m—that is, from level 2 plus two shuttles of level 3 to the end of level 8—with mean values of 345, 376, and 378 m for the three trials (fig 3A). No patient completed this 12 level protocol. There was a significant difference in patients' per-

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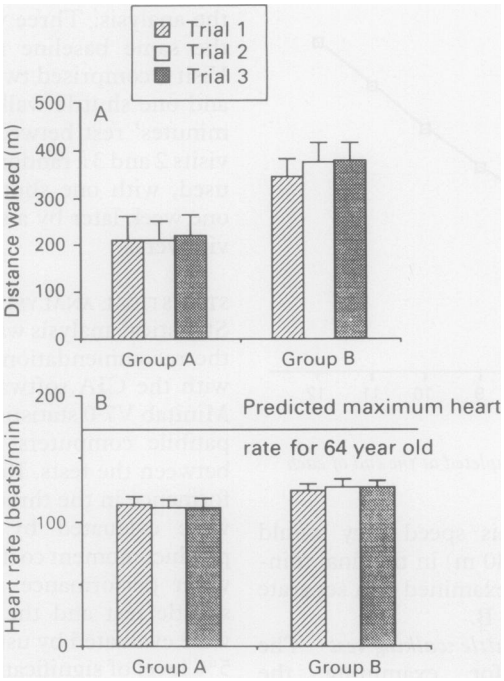

Figure 3 A—Mean (SE) distances walked in the shuttle walking test: groups A and B. B—Mean (SE) heart rate during the shuttle walking test: groups A and B.

formance between trials 1 and 2 but not between trials 2 and 3, suggesting a small training or learning effect. Mean maximal heart rates were 125, 128, and 127 beats/min for trials 1, 2, and 3 (fig 3B). The relationships between the distances walked on each trial were strong (table 3)—for example, r = 0·98 for trial 2 *v* trial 3. Table 3 shows that for 95 patients out of 100 the recorded walking distance in trial 3 would be within −21·9 to 17·9 m of that recorded for trial 2. The mean difference between these two trials was −2 m.

As with other studies examining patients' performance,[1 11 12] there was a poor correlation with patients' lung function values. For FEV_1 *v* walking distance r = 0·51, 0·22, and 0·25 for trials 1, 2, and 3.

COMPARISON OF THE SHUTTLE AND THE SIX MINUTE WALKING TEST (GROUP C)

The results of the second shuttle test (modified protocol) and the third six minute walking test were used for the comparison of the two tests. The distance recorded for the shuttle test represents completed shuttles only. The relationship between performance (distance completed) in the six minute walking test and in the shuttle test was moderate (fig 4, ρ = 0·68).

In nine of the 15 patients the maximal heart

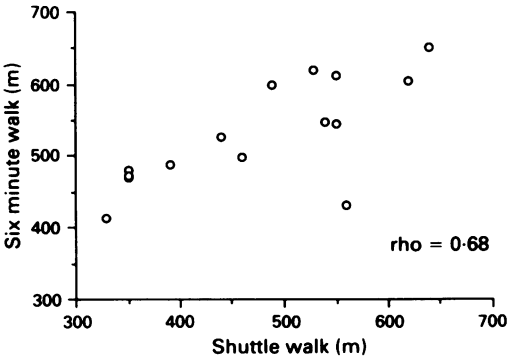

Figure 4 Distances walked in the shuttle walking test and the six minute walking test: group C.

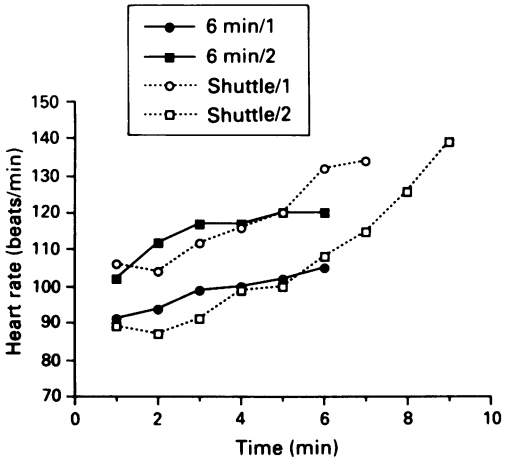

Figure 5 Heart rate responses during the shuttle walking test and the six minute walk for two representative patients from group C.

rate was greater for the shuttle test than for the six minute walking test. The correlation between heart rates for the two different tests was moderate (r = 0·76). The mean maximal heart rate was 9 beats/min higher in the shuttle test than in the six minute walking test (95% CI 1 to 18 beats/min). Figure 5 shows the heart rate recorded at the end of every minute of each test for two representative patients. This shows a graded cardiovascular response to the shuttle test, which was not observed in the six minute walking test. The mean increase from resting heart rate values was significantly smaller for the six minute walking test (41 (SD 22), range 8–86 (beats/min) than the shuttle walking test (55 (21), 29–91 beats/min).

The Borg breathlessness scale rating[7] was higher at the end of the shuttle walking test than at the end of the six minute walking test in nine out of 15 patients. Two patients reported greater breathlessness after the six minute walking test and one of these patients had a higher level of perceived breathlessness at rest on the day of the six minute walking test than on the day of the shuttle test (scores 4 and 0·5). The correlation of the Borg breathlessness scale responses at the end of the shuttle walking test and of the six minute walking test was ρ = 0·64. The maximum recorded Borg scale scores were nine for the shuttle test and seven for the six minute walking test (not in the same patient).

Discussion

The performance of patients with chronic airways obstruction is limited by breathlessness that is due to a mixture of functional abnormalities. The limitation to individual performance cannot, however, be predicted by the measurement of these factors alone.[13] Observation of the exercise response has therefore become the basis of objective assessment of disability both to stress the cardiorespiratory system and to evaluate reserve capacity.

It has been proposed that day to day activities are mostly of an irregular nature, a

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steady state rarely being achieved.[14] Consequently, patients' symptoms are probably more likely to be revealed or identified during an incremental exercise test rather than a self paced exercise test. The six and 12 minute tests have no standardised pace or incremental facility. Whether the cardiorespiratory system is stressed maximally depends on the manner in which the test is conducted and the amount of encouragement offered. Inconsistencies of this nature probably contribute to the considerable variation in the walking performance reported for clinically similar groups of patients between studies.[4 15 16] This makes it difficult to make valid comparisons between studies.

The shuttle test fulfils the basic criteria for an exercise test for pateints with chronic airways obstruction. It is based on a familiar activity and, unlike cycle ergometry or treadmill walking, is simple for both the operator and the patient. It requires minimal equipment and has the advantage that it is standardised, incremental, and externally paced, diminishing the effect of the operator's influence.

Although the operator walks alongside for the first minute in the shuttle walking test this does not encourage the patient to walk faster because pacing is imposed by the audio signal. It does, however, help the patient to establish the slowest speed of walking and therefore creates the base speed on which to increase speed. In the first minute it was usually necessary to slow the patient down as the less severely affected patients found it difficult to walk slowly enough. Although the operator then sits alongside the course no encouragement is offered and his or her influence is minimised because the external pacing does not allow the patient to walk faster.

External pacing allows valid intersubject and intrasubject comparison. Patients who have completed 500 m in an incremental walking test have experienced a similar "work rate/stress." This is not necessarily the case for patients completing similar distances in the self paced six or 12 minute walking tests and therefore any conclusions regarding their respective functional capacities would be invalid. It has been suggested that the habitual nature of walking may prevent a self paced test from fully showing the possible beneficial effects of any treatment.[12] The shuttle test may enable more effective comparison of different approaches to patients' management and treatment than has previously been possible with existing field exercise tests. Interestingly, the one patient who performed strikingly better in the shuttle test than in the six minute walking test (fig 4) found it difficult to pace himself for the six minute walking test on all three occasions. The extent of his disability was shown more clearly by the shuttle test than by the traditional six minute walking test.

Examining the results from the downgraded protocol we thought that the development of an alternative protocol would be appropriate. This conclusion was based on two observations. Firstly, the FEV_1 values of group A were low (mean value 0·5 l) and, secondly, one patient from group A completed the 10 level protocol. These two factors indicate that the patient suffering from mild chronic airways obstruction would probably complete the course with relative ease. An extended protocol was therefore required to evoke a symptom limited maximal performance in these patients. Secondly, a slower start was clearly necessary to accommodate the more severely affected patient. We identified the modified 12 level protocol as a suitable shuttle walking test protocol for assessing functional capacity in a wide range of patients with chronic airways obstruction, with a greater increase of walking speed to stress the more able patients as well as a slower start than the downgraded protocol to cater for the more severely affected patients. A measure of functional capacity can be therefore obtained in most patients with the modified shuttle walking protocol. The reproducibility of the shuttle walking test can be examined and reinforced by using the results of both protocols as the structure and procedure of these externally paced walking tests were the same. Consequently, the modified protocol was used for the second stage of the study. Furthermore, only one practice walk appeared to be necessary. The patients in group B performing this modified protocol walked significantly further in the second and third trial than in the first, suggesting that meaningful results can be obtained after just one practice walk. Reproducible results are obtained regardless of whether the patient completes one level (one minute) or 12 levels (12 minutes).

The defined speeds of walking in the shuttle test ensure that the work load increases in a manner that provides an incremental and quantitatively similar cardiorespiratory stress for all the patients. The heart rate response (fig 5) provides evidence of this graded cardiovascular response, not observed in the six minute walking test. The shuttle test, unlike the six or twelve minute walking tests, where effort may be maximal from the start, stresses the patient progressively to a symptom limited maximum. This gradual increase in exercise intensity increases the safety of the test. Consequently, the shuttle test may reveal cardiovascular limitations to exercise and may have the potential for use as an exercise test for conditions other than lung disease. Secondly, the shuttle test can yield an outcome measure that is easily applied to exercise rehabilitation for patients with both cardiac and respiratory conditions. The mean maximal heart rates obtained in our patients (fig 3B), however, are clearly lower than would be expected for the median age of the group, which is consistent with a ventilatory limit to functional capacity in these groups. We anticipate that the shuttle walking test will have a role in the prescription of exercise in this group of patients. By calibrating a patient's response to the test (heart rate, Borg scale) a suitable walking speed can be judged for a training programme.

It has been reported that an externally paced step test is a reproducible and standardised method of assessing functional capacity in normal subjects.[17] The performance of patients with severe chronic airways obstruction in a

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paced step test, however, shows a pronounced learning effect.[12] A 96% improvement in performance over the first four tests has been reported. In the same study patients were also observed to have a lower ventilatory response and therefore maximal oxygen uptake ($\dot{V}O_2$ max) response to a self paced walking test than to the paced step test. This indicates that patients tend to select a speed that is comfortable rather than stress themselves with a symptom limited performance. They would consequently fall short of attaining their $\dot{V}O_2$ max in a self paced walking test.

The step and the shuttle walking test both use less space than a self paced corridor test. Stepping may not be a familiar activity and coordination may be difficult for this group of patients. Limitation to this type of exercise may in practice be muscle weakness or soreness rather than ventilation. In addition, the step test appears to have poor reproducibility.[12] The shuttle walking test offers an alternative to the self paced walking test and the paced step test and is a substitute for both.

The modified shuttle walking test we have described is, after one practise walk, a reproducible, easily administered, standardised exercise test of functional capacity in patients with chronic airways obstruction. We recommend its use for the objective assessment of patients with a wide range of respiratory disability.

The shuttle walking test tape and instruction leaflet may be obtained from the department of respiratory medicine, Glenfield General Hospital, Leicester LE3 9QP.

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