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Exercise Training for Performance and Health

Körperliches Training für Leistungsfähigkeit und Gesundheit

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ZUSAMMENFASSUNG

Körperliches Training fördert die Gesundheit und körperliche Leistungsfähigkeit. Eine große Ansammlung wissenschaftlicher Literatur belegt die positiven Effekte körperlicher Aktivität in einer semiquantitativen Art und Weise. In diesem Artikel werden aktuelle Studien zur Trainingsdosis mit normalen Individuen (Schritte pro Tag) und Athleten (Volumen und Intensität von Trainingsläufen in Vorbereitung auf Marathonläufe) präsentiert. Zusätzlich werden auch Studien vorgestellt, die mittels der RPE Methode und dem ‚talk test' Trainingsintensitätsbelastungen von Athleten sowie gut trainierten Breitensportlern überwachen. Abschließend werden Daten zu ‚Pacing' Strategien mit Herzpatienten aus neueren Studien vorgestellt. Die zusammengefassten Daten in dieser Übersicht sollen dazu dienen eine kompetente Beratung zur Trainingsgestaltung für jedes Fitnesslevel zu ermöglichen, mit der Absicht individuell gesetzte Ziele bezogen auf körperliche Leistung und Gesundheit zu erreichen.

Schlüsselwörter: Training, Gesundheit, Sport, Verordnung.

SUMMARY

Exercise training is an important positive activity for both health and performance. A rich literature demonstrates, in a semi-quantitative way, the value of exercise. However, knowledge about how to improve the process of giving exercise advice is always important. This paper reviews recent studies relative to exercise dosimetry in both normal individuals (steps per day) and athletes (the volume and character of training runs in preparation for marathon races). It also provides data regarding the use of the Session RPE (rated perceived exertion) method and the Talk Test to monitor training load and control training intensity in well-trained individuals and athletes, respectively. Lastly, evidence extending recent findings on pacing strategy into a new population (patients with cardiovascular disease) is presented. In total, the new data presented in this manuscript add information that may be useful in refining the process of advising exercisers at all levels on better ways to achieve their exercise goals.

Key Words: Training, health, sport, prescription. .

PROBLEMS AND OBJECTIVES

Exercise is one of the most unequivocally positive things that humans can do. Whether training for athletic performance or for a healthy lifestyle, the value of increasing levels of exercise can hardly be overstated (4,5,11). The beneficial adaptations to exercise are based primarily on the ability to cause gene expression and protein synthesis that contribute, in a mode specific way, to both performance and health. Although there are a variety of reports (5,15,28), and professional society guidelines (19) about the quantity, quality and pattern of exercise training necessary to achieve the goals of exercise training, there is always the need to further refine the prescription of training programs. For example, guidelines that recommend 30 minutes of moderate intensity exercise, performed on most days of the week (19) are similar to recommendations of 10,000 (or even more) steps per day (2,30), although the agreement between the methods is not entirely clear. At the other end of the continuum, information about how to prepare for athletic challenges (e.g. marathon running) have recommendations about the total volume of training and the value of specific (e.g. long runs) training, but little quantitative evidence related to the outcomes of training (9,18,29). Similarly, although there are established guidelines regarding prescription of exercise based on relative heart rate (e.g. % heart rate reserve) or metabolic intensity (e.g. $\%VO_2$ reserve), these recommendations universally suffer from the limitations of the 'relative percent concept' (22,26) (e.g a particular relative percent of $\%VO_2$ reserve is not equivalently demanding in different individuals). It has been recognized for more than a generation that training prescription based blood lactate or ventilatory responses to training is inherently superior to relative percent methods (3,20,23,24,27). However, the technical requirements for such prescription have prevented its' wide use. Recent studies of the Talk Test (a surrogate of ventilatory and lactate threshold) (8,13,25,31) and of the ability of the Talk Test to 'translate' exercise testing results to absolute exercise intensity (17,21) suggest the applicability of this very simple technology. Lastly, recent interest of pacing strategy in athletes (16) and the association between unaccustomed heavy exercise and medical complications related to exercise (14), suggest that information about pacing needs to be extended to non-athletic populations. Thus, despite the very good knowledge about how to prescribe exercise for performance and health, there is always a need to improve upon the 'state of the art'. Indeed, beyond the limitations of the 'relative percent concept' already discussed, the range of relative percents recommended in professional guidelines (19) is so broad as to be of little practical help during the process of exercise prescription. This paper is designed to discuss recent data from our laboratory which addresses these issues.

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MATERIAL AND METHODS

The presented data are the product of five previously unpublished investigations into monitoring the volume and intensity of exercise and the pattern of energy use during exercise training. All studies were approved by the local ethics committee and all subjects provided written informed consent.

In order to compare 'time structured' versus 'steps per day structured' related exercise, Study 1 was performed by measuring of the daily time that structured exercise was performed versus the total 'steps per day' accumulated (including both normal activities and structured exercise). Subjects, ranging from healthy university personnel to clinically stable cardiac patients (8 males age 51 ± 12y, 12 females, age 44 ± 15y) recorded their steps per day on an electronic pedometer and the number of minutes of structured exercise each day for two consecutive weeks. The first week included the normal level of exercise performed by the subjects. In the second week the subjects were asked to increase the amount of walking as much as possible. The average steps • d^{-1} and minutes of structured exercise • d^{-1} was recorded over the entire week in order to prevent any one atypical day from overly influencing the results. The intrinsic logic of this study was that by comparing structured exercise time to steps taken per day, that these two methods of recommending exercise could be unified. Obviously, non-ambulatory exercise cannot be evaluated in terms of steps per day, but the translational logic to minutes per day is assumed to be valid.

Study 2 surveyed training and performance information of ~500 marathon runners during several marathon races, all contested in good environmental circumstances. The subjects represented a wide range of age (20-66 years) and abilities (2:24-5:10), 60% were male. Information about training volume and number of long (>32 km) runs in the 8 weeks preceding each race, together with race performance, including the slowdown during the last 10 km were gathered using questionnaires, and analyzed relative to the performance of groups of runners with varying performance. The groups were formed from natural divisions of performance times. Some of these data were published many years ago in the non-peer reviewed literature (9), although the current analysis is unique.

To extend our understanding of the validity of the Session Rating of Perceived Exertion (RPE) method (10,12), Study 3 compared session RPE (a global rating of overall perceived exercise intensity, gathered 30 min following the conclusion of exercise (10)) with the average RPE (measured every 10 min) achieved during a 60-min exercise bout in very well-trained non athletes (6 males, 22 ± 3y, $VO_2max = 55 \pm 4$; 6 females, 20 + 1y, $VO_2max = 47 \pm 5$).

In Study 4 we observed heart rate, blood lactate, RPE and the speech comfort (17,21) during bouts of steady state exercise in competitive runners (9 males, 22 ± 10y, $VO_2max = 67 \pm 9$; 5 females, 29 ± 9y, $VO_2max = 51 \pm 3$). Each subject performed an incremental exercise test, with measurement of the Talk Test (17,21) to define exercise intensities relative to the ability to speak comfortably. The Talk Test is performed during incremental exercise, by having the subjects recite, aloud, a standard 31 word paragraph at the end of each 2 min exercise stage. The subject is then asked "can you speak comfortably?" Only 3 answers are allowed: "yes", wich we refer to as a Positive Talk Test; "yes, but……", which we refer to as an Equivocal Talk Test; and "no", which we refer to as a Negative Talk Test. Subsequent, steady state exercise bouts were performed at intensities associated with the Equivocal stage, the Last Positive stage, or the stage before the Last Positive stage (LP-1) of the Talk Test during incremental exercise.

Lastly, in order to gain a better appreciation of how cardiac patients learned to pace their exercise intensity, a critical issue in terms of the safety of exercise, we observed a group of patients in a cardiac rehabilitation program (6 males, 63 ± 13y; 6 females, 61 ± 6y) during four performances of the 6-minute walk test. This test is a widely popular sub-maximal exercise test, used for both training and outcome evaluation (1). The walks were separated by ~1 week, and the patients were instructed to walk at the fastest pace at which they were comfortable. Pace was measured over each 30 s of the 6 min test.

Table 1: Comparison of a week of normal ambulation and a week when subjects are encouraged to 'walk as much as possible' in terms of the total steps per day, the unstructured steps per day (moving around at work), structured exercise (moving around with the specific intent to exercise), and the number of minutes of structured exercise.

	Week 1	Week 2
Total Steps•d^{-1}	11,584 + 2720	18,654 + 1927*
Unstructured Steps•d^{-1}	7,444 + 2759	7,510 + 2844
Structured Steps•d^{-1}	4,143 + 2665	11,146 + 2512*
Time (min•d^{-1})	43 + 33	116 + 50*

* $p < 0.05$ vs Week 1

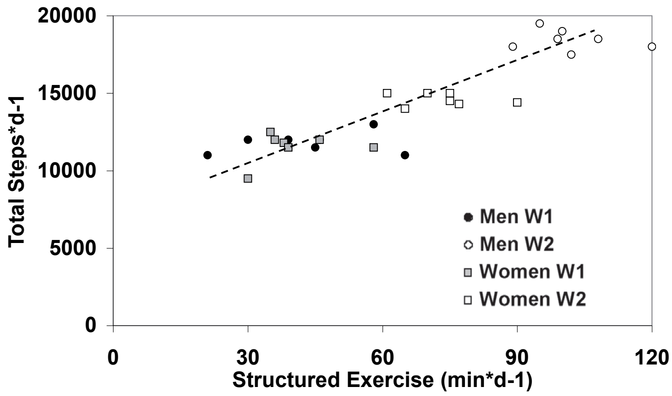


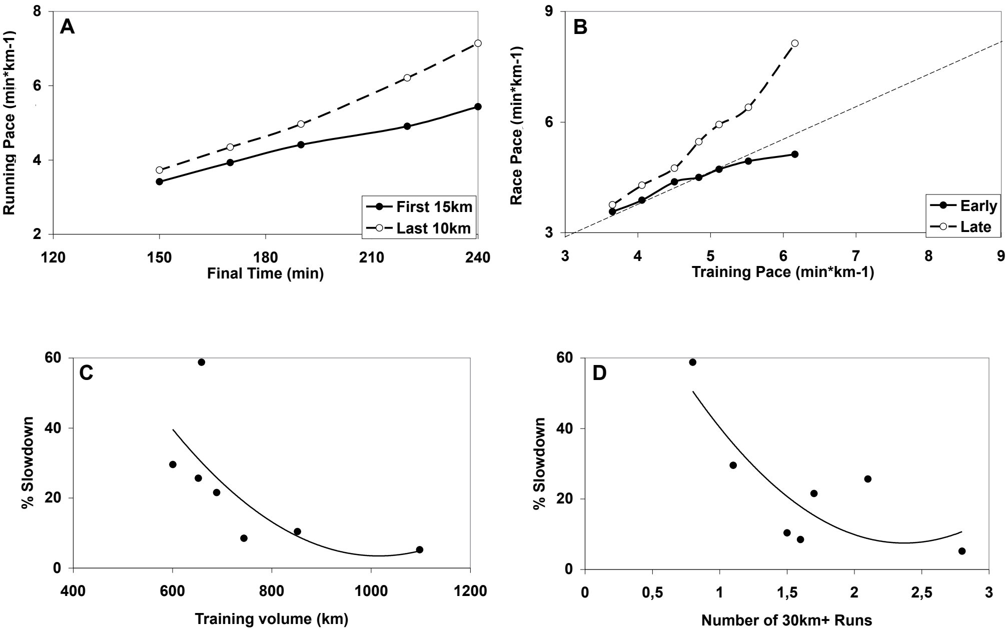
Figure 1: Relationship between the minutes of structured (e.g. intentional) exercise and the total steps accumulated per day in a diverse sample of adults. The values represent averages obtained during successive weeks of monitoring normal ambulation and a week when the subjects were encouraged to 'walk as much as possible'.

RESULTS

Study 1: There was a significant increase in the number of total and structured steps during the week when we asked the subjects to walk as much as possible (Tab. 1), associated with an increase in the minutes of structured exercise. The number of steps not associated with structured exercise remained unchanged. The number of steps in the second week approximated the amount observed by Bassett et al. (2) in Amish farmers, living a lifestyle similar to

19th century agriculturalists. The overall relationship between the time of structured exercise in relation to the steps per day is presented in Figure 1. There are several obvious relationships evident in the data, including the close approximation of 30 min of structured exercise vs 10,000 steps per day (30), 70 min vs 15,000 steps per day (2) and 120 min vs 20,000 steps per day, which may approximate estimates of the exercise load undertaken by hunter gatherers (7) (Fig. 1).

Study 2: Observations of subgroups revealed that faster marathon runners are faster both because of a faster early running pace and because of a less pronounced slowdown during the last 10 km (Figure 2). It is also evident that faster runners (<3 hr) run at approximately their normal training pace in both the early (first 15 km) and late (last 10 km) race segments. However, the slower runners run much faster than their training pace during the first 15km of the race, and much slower during the last 10 km of the race, suggesting that in addition to being inadequately prepared generally they may also be making a pacing mistake. The normalized slowdown (pace in last 10 km-pace in the first 15 km), evaluated in terms of training volume (with 800 km in the 8 weeks preceding the race used as a reference (9, 18, 29) shows that low training volume runners have slowdowns proportional to their lack of appropriate training volume. This is also evident when slowdown is evaluated relative to the number of long (>30 km) runs or the product of training volume and long runs (Fig. 2).



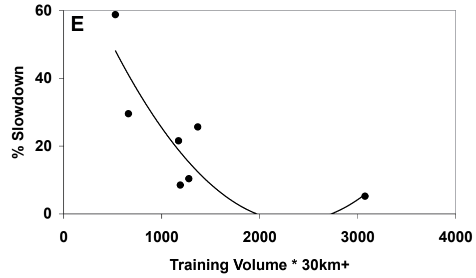


Figure 2: Responses to questionnaires by ~500 marathon runners, grouped by performance ability. The final time is obviously related to the running pace during the first 15 km, but especially to the running pace in the last 10 km, demonstrating that slower runners are slow as much because they are slow in the last 15 km as because of their slower early running pace (upper left); that faster marathoners (<3 hr) run near their average training pace during the entire race, but that slower runners run much faster than their normal training pace early in the race, and much slower than their normal training pace late in the race (upper right); and that the magnitude of slowdown during the last 10 km (compared to the first 15 km) is related to the total volume of training performed in the 8 weeks prior to the race (middle left), to the number of long (>30 km) runs completed (middle right), and to the product of training volume and number of long runs (lower left).

Study 3: The response of RPE during 60 min bouts at the intensity associated (during incremental exercise) with the Equivocal, Last Positive, and the stage before the last positive stage (LP-1) of the Talk Test are presented in Figure 3, together with the relationship between the average RPE during the bout and the Session RPE. There was the expected 'drift' of RPE during the course of the exercise bouts, which was more evident at higher exercise intensities. In general, the LP-1 stage during incremental exercise was the highest workload associated with stable exercise responses during 60 min of sustained exercise, which agrees with our earlier findings in well-trained non-athletes (21). However, these well-well trained subjects seem to be able to tolerate sustained exercise at a higher intensity (relative to incremental exercise Talk Test responses) than sedentary individuals (17). With the exception of bouts where the average RPE was very high (>7), there was a good correspondence between mean and Session RPE. In very hard training bouts, the Session RPE was greater than the mean RPE, suggesting that the RPE during the latter part of the bout contributed disproportionately to the Session RPE (Fig. 3).

Study 4: Responses of heart rate, blood lactate, RPE and speech comfort during 30 min of exercise in athletes are presented in Figure 4. The subjects demonstrated steady state conditions at the absolute intensity associated with the last positive stage of the Talk Test, but were clearly outside steady state conditions at the intensity associated with the equivocal stage of the Talk Test. The results in this population of athletes are similar to those of Jeans et al. (21) in well trained individuals, but different from the findings of Foster

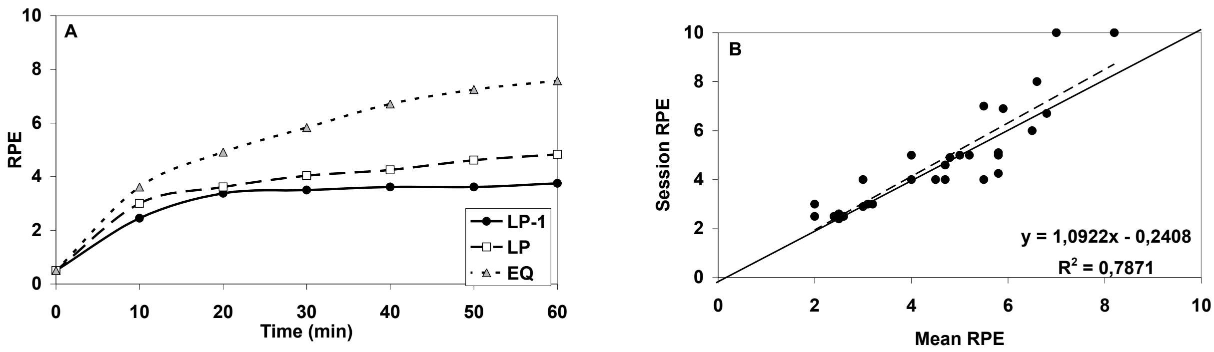


Figure 3: Growth of the momentary value of RPE during 60- min exercise bouts in well-trained non-athletes at fixed intensities defined by responses to the Talk Test during incremental exercise (upper). At intensities at or less than the last time the subject could still speak comfortably (LP and LP-1), the growth of RPE was moderate and in the range normally prescribed for fitness exercise. At intensities where the subject could not unequivocally speak comfortably (EQ), the growth of RPE was rapid during the exercise bout and achieved values well above conventional recommendations. The average RPE during the exercise bouts was generally well-related to the Session RPE assessed 30- min following the work bout (lower). At very high mean RPE values, it appears that the terminal values biased the Session RPE upward.

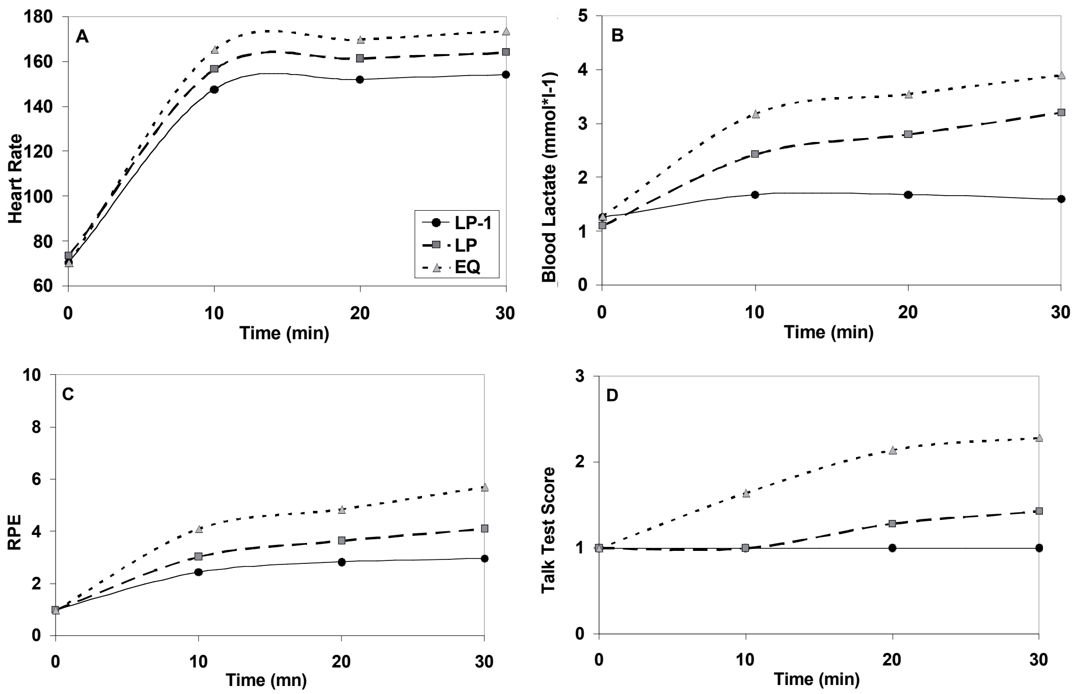


Figure 4: Responses during constant intensity exercise bouts at intensities defined by Talk Test responses during incremental exercise in competitive runners. At intensities at or less than the last time the subject could still speak comfortably (LP and LP-1) the response pattern of heart rate, blood lactate, RPE and speech comfort was indicative of steady state responses. At intensities where the subject could not unequivocally speak comfortably (EQ), the response pattern was not consistent with steady state conditions.

et al. (17) in sedentary individuals (who only reached steady state conditions at the stage before the last positive stage of the Talk Test (LP-1)) (Fig. 4).

Study 5: The velocity pattern during repeated trials of the 6-minute walk test in cardiac rehabilitation patients are presented in Figure 5. In concert with our earlier findings of pacing patterns in well-trained non-athletes, there was evidence that the subjects 'held back' during the first trial, and particularly during the first half of the first trial. With successive trials, the early pace was progressively faster, and over the last 2 trials resembled the U shaped (fast start, steady pace middle, endspurt) velocity curve often seen in athletes during competition (16). These data support the hypothesis that humans regulate their exercise behavior in a way designed to minimize the likelihood of catastrophic homeostatic disturbances. Just as athletes avoid a too aggressive early pace, in order to prevent a large decrease in pace midway through the event (a competitive catastrophe), patients regulate their early pace in a way that probably avoids myocardial ischemia, at least with new tasks. With experience that performing a task in a particular way did not cause harm, they appear to be willing to start the task more vigorously. Data on the 6-minute walk test may be limited by the inability to actually walk at faster paces. Future studies will need to focus on criterion activities that are not limited by the mechanics of walking. There also appears to be some 'microvariation' in pacing amongst the patients, which has also been observed in athletes in competition (C. Thiel, unpublished observations). Whether this is strategic, or simply a response to short term homeostatic disturbances awaits higher resolution data of walking speed within the 6-min walk test (Fig. 5).

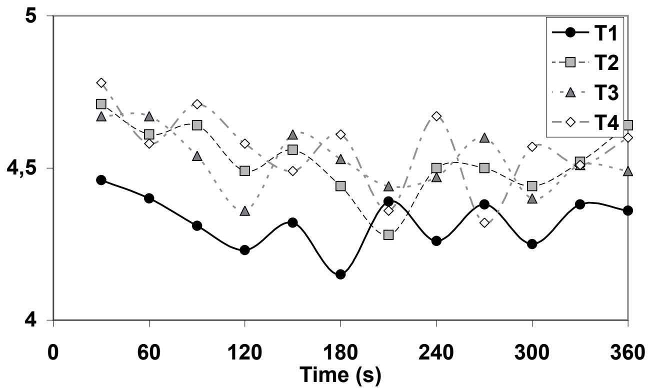


Figure 5: The pattern of walking speed (e.g. pacing pattern) in cardiac rehabilitation patients during successive trials of the 6-minute walk test. As is seen in healthy athletic individuals, there is a tendency to hold back during the first trial, particularly during the trial. The results are consistent with the concept that exercise intensity is regulated in a way designed to prevent unreasonable levels of exertion at the end of the task, and that as the patients gain familiarity with the task they appear more willing to aggressively pace the activity.

DISCUSSION

The results of these studies expand our understanding of how to better prescribe exercise for both performance and health. Our results support the concept that ~30 min • d-1 of structured exercise (19) is comparable to 10,000 steps • d-1 (30), and also suggest that ~70 min • d-1 is comparable to the 15,000 steps • d-1 of 19th century agriculturists and 120 min • d-1 is comparable to the 20,000 steps. d-1 performed by hunter-gatherers (7). It is also evident that both training volume and the number of specific long-run training sessions combine to determine the performance of marathon runners (9,18,27), particularly in less well-trained competitors. Our use of the Session RPE as a surrogate for the average training intensity during exercise bouts (10,12) appears to be justified by the results of these studies, although there is apparently a variance during very hard training sessions. The Talk Test, a surrogate of the ventilatory threshold, appears to be a viable method for prescribing exercise in competitive runners, just as has previously been show in less well-trained individuals (17,21). Lastly, it appears that, just as athletes learn to pace themselves during novel tasks, patients learn pacing during successive repetitions of the 6-minute walk test. This is important since, inappropriate pacing can lead, not to the competitive failures that athletes experience, but to catastrophic medical emergencies. In sedentary individuals, and in patients with exertional ischemia, there is good evidence that unaccustomed heavy exercise and/or exercise above the ischemic threshold can lead to triggering of myocardial infarction or to dysrhythmias (14). We have previously presented evidence that maintaining the ability to speak comfortably keeps patients with cardiovascular disease below the threshold of exertional ischemia (6). The present results, of a learning strategy during the 6-min walk test suggest that patients should be strongly encouraged to 'work at their own pace', as there is good evidence that being 'hurried' or 'driven' by an external pacemaker during exercise can contribute to complications during exercise (14).

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