EXERCISE PRESCRIPTION WHEN THERE IS NO EXERCISE TEST: THE TALK TEST

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Abstract:

The Talk Test is a subjective measure of exercise intensity which, like RPE, has come to be accepted as an alternative to objective measures (%HRR, %VO_2max) for exercise evaluation and prescription. This paper reviews the history and indications for using the Talk Test as a tool for both exercise evaluation and exercise prescription. The Talk Test, in one form or the other, has a long history, dating from at least 1937. It appears to be robust relative to the method of provoking speech and to the exercise mode. In the most widely used version, the subject recites a standard paragraph of 30-100 words, and responds to the question 'Can you speak comfortably?' With answers of 'Yes' (POSITIVE), 'Yes, but…' (EQUIVOCAL), and 'No" (NEGATIVE), the Talk Test appears to be able to identify exercise intensities closely associated with the ventilatory (VT) and respiratory compensation (RCT) thresholds, and to bracket subjects into %HRR intensities closely associated with the accepted exercise/training intensity guidelines, without the need for performing a maximal exercise test. The Talk Test appears to work well in a range of populations from college students, healthy adults, elite athletes to patients with chronic diseases. It also seems to be a valid and reliable marker of the presence of exertional ischemia. In a variety of populations, the Talk Test appears capable of being translated into absolute exercise training intensities, on the basis of a commonsense step down sequence. The Talk Test appears to work by allowing detection of when the suppression of breathing frequency, which is necessary for speech, begins to lead to CO_2 trapping, which interferes with breathing comfort. Its response to disrupting stimuli such as stochastic exercise, exercise training and blood donation follow predictable patterns. Guiding exercise intensity using the Talk Test instead of %HRR provides comparable responses during exercise training, without the need for an anchoring maximal exercise test. In summary, the Talk Test seems to offer a considerable promise as a means of exercise evaluation and prescription, in a wide variety of exercising individuals, without the need for a preliminary exercise test.

Key words: *exercise prescription, breathing, ventilatory threshold*

Introduction

Systematic exercise training contributes to large scale physiological adaptions, associated both with improved health (Blair, et al., 1989, Arem, et al., 2015) and enhanced exercise capacity (Foster, Daines, Hector, Snyder, & Welsh, 1996, Sylta, et al., 2016, Porcari, et al., 2018). These adaptations are based on favorable changes in gene expression (Booth Gordon, Carison, & Hamilton, 2000) leading to augmentations of protein synthesis in the organ systems that contribute to the ability to perform, and support, muscular activity. Functional capacity attributable to these changes in gene expression is a useful surrogate of several markers of health (Booth & Roberts, 2008). From a historical perspective, these adaptations remind us of the account of Milo of Crotona, the Italian farm boy who daily lifted a growing bullock, and in so doing became the strongest man in the world, a six times champion of the Classical Olympic Games, and later a great military leader. The simple principle of progression that Milo followed has evolved into the concept of exercise prescription, where a variety of descriptors of exercise training (frequency, intensity, time, volume and progression) (Riebe, 2017) are combined to create a training scheme where desirable outcomes will be achieved in a predictable manner, while minimizing the side effects of exercise training. Although serious side effects from exercise training are comparatively rare (Foster, et al., 2008a), less serious musculo-skeletal side effects can reduce long term adherence to an exercise program, and prevent achieving desired effects. Because individual exercise needs vary substantially, based on individual goals, current exercise capacity, health status and age, managing the components of the exercise program into a 'prescription' is central to achieving all goals – athletic, fitness and clinical. There is a large body of knowledge, primarily grounded on changes in the maximal oxygen uptake (VO_2max) in relation to increases in the frequency, intensity and time of exercise programs in previously sedentary individuals (Garber, et al., 2011; Pollock, 1973; Riebe, 2107). This body of knowledge has been extended into clinical practice (Ross, et al., 2016) and forms the underlying body of knowledge for the practice of clinical exercise physiology. More recent consensus statements, based on the known weaknesses in the gold standard 'relative percent concept' of exercise prescription (Katch, et al., 1978, Sharhag-Rosenberger, et al., 2010), have focused on the use of threshold concepts as the basis for prescribing exercise (Mezzani, et al., 2012) and on the intensity distribution scheme of exercise training (Seiler, 2010; Sylta, et al. 2016). Although not as systematically organized, there is also an appreciable body of knowledge related to improved performance in athletes in relation to elements of the exercise training program (Billat, et al., 1999; Foster, Daines, Hector, Snyder, & Welsh, 1996; Orie, Hofman, de Koning, & Foster, 2014; Seiler, 2010; Sylta, et al., 2016; Foster, et al., 2012).

Regardless of the scheme for prescribing exercise, the process has been historically linked to physiological responses observed during incremental exercise testing. This procedure allows the identification of one or more markers: maximal exercise capacity (max Power Output, VO_2max or maxMETs), resting (HRR) and maximal heart rate (HRmax), ventilatory (VT) and respiratory compensation (RCT) thresholds, and lactate thresholds (LT, MLSS), all of which are of established value within contemporary schemes of prescribing exercise (Condello, et al., 2014; Foster & Thompson, 1991; Foster, Thompson, & Betes, 1991; Mezzani, et al., 2012; Reibe, 2017; Ross, et al., 2016). However, incremental exercise test results are not widely available, whether in athletic, fitness or clinical settings. Certainly less than 5% of exercisers, and maybe as few as 1%, have a well done exercise test prior to beginning of an exercise program, and still fewer have follow up tests, appropriate for modifying the exercise prescription. This paucity of incremental test results is attributable to a combination of the substantial cost of appropriate equipment and the need for trained personnel (sometimes including medical practitioners) to perform and interpret the procedures. Even in clinical exercise based rehabilitation settings, the few exercise tests performed are designed to evaluate continuing pathophysiological responses or to define prognosis (Myers, et al., 2002; Ross, et al., 2016). As such, they may not have information that is useful for prescribing exercise.

Given that incremental exercise testing, which forms the backbone of exercise prescription algorithms (Mezzanni, et al., 2012; Riebe, 2017) is largely absent in non-research settings, there has been a considerable interest in the use of subjective methods of prescribing and guiding exercise programs. There is evidence that the rate of increase of the Rating of Perceived Exertion (RPE) in relation to workload during submaximal incremental exercise can be used to make robust estimates of VO_2max (Eston, 2012). There is also evidence that training at intensities defined solely in terms of RPE (rather than the target heart rate) can provoke appropriate changes in VO_2max and VT (Parfitt, Evans, & Eston, 2012). Further, there is a broad body of evidence that RPE can be a useful tool for both evaluation and prescription (Eston, 2012). The use of RPE as an evaluative and prescriptive tool is mature enough that there are summary texts available (Borg, 1998) including guidelines for using multiple versions of the RPE scale (Borg & Kaijser, 2006). Recent evidence demonstrates that, with slight modifications, RPE can be used to evaluate the intensity of entire exercise sessions (Foster, et al., 1995, 2001), provide an estimate of exercise training load sufficient to monitor the progress of an exercise training program (Foster, et al., 1995; Foster, Rodriguez-Marroyo, & de Koning, 2017a) and suggest the broad utility of RPE as a subjective surrogate for formerly "gold standard" methods of exercise evaluation and prescription.

Talk Test

Another subjective method of exercise evaluation and prescription, the Talk Test (TT), has received considerable attention over the past two decades. The Talk Test is a conceptually simple process, experienced by almost every human with some frequency. Assume that you are walking, or running, or riding with a friend, and carrying on a conversation. At some point, one of you increases the pace slightly, or the land becomes slightly more uphill, and you find that completing your sentences (e.g., speaking comfortably) becomes more difficult. You may turn to you companion and say something the effect 'If we're going to keep talking, you have to slow down'. The same effect may be realized by asking someone to perform progressively harder exercise, and recite a standard paragraph, either from memory or a cue card. They have to speak out loud, and when the recitation is complete, you ask them: "Can you speak comfortably?" During mild exercise most people will reply with "Yes". However, at some point, which is usually pretty distinct, they will answer "Yes, but….". This equivocation in speech comfort provides important information about the sustainability of exercise at that intensity. Still later, at a higher intensity, they may begin to recite the paragraph, then quit part way through it, and say something to the effect "No, I can't speak anymore". This also tells you that the sustainability of exercise is very short at this intensity. We, and others, have used standard paragraphs. One paragraph, "the Rainbow Passage" is 101 words, and is drawn from the speech pathology literature. While it is mostly designed to reveal difficulty with pronouncing certain sounds, it provides a convenient stimulus to speech. Unfortunately, it is not something that most people know from memory, so it requires a cue card to be used. Culturally grounded sayings (e.g., the Pledge of Allegience in the U.S.) are known from memory by almost everyone, and can be used as more convenient stimuli (Shafer, Foster, Porcari, & Fater, 2000). One alternative approach is to have a standard interview (e.g., "Tell us about your family structure" or "Tell us about what you had for breakfast this morning"). At the beginning, most people will comfortably answer the question. Later, at a higher intensity, they will self-identify that they cannot talk anymore. Another alternative approach is to have the exerciser, while still at rest, take a deep breath and then count, out loud (one, one thousand; two, one thousand) for as long as they can on a single breath. The higher the intensity of exercise, the shorter will be the counting duration. All of these strategies are designed to force someone to speak, out loud, in a repetitive way. Lastly, in the situation where it is inconvenient to speak out loud while exercising (some people just feel silly doing this) the sense of respiratory effort using RPE for respiratory effort has been linked to the stages of the TT. Mikat, Dubiel, Foster, and Porcari (2015) demonstrated that a respiratory effort of 4 on the 0-10 Category Ratio scale (i.e., 'somewhat hard') approximated the LP stage of the TT. Similarly, a respiratory effort of 5 ('hard') was associated with the EQ stage of the TT, and a respiratory effort of 6.5 was associated with the NEG stage of the TT. During paired gas exchange studies, a respiratory effort RPE of 4 was associated with the VT, and 6.5 with the RCT. Thus, it is likely that most habitual exercisers will come to recognize a certain 'feel' for the right intensity of exercise based on breathing effort. However, for beginning exercisers and patients with chronic disease, both of whom may need active guidance regarding exercise intensity during the first several training sessions, a device like the Talk Test can provide useful guidance. It is also of interest to note that the respiratory effort at the LP stage of the TT ("somewhat hard"), matches with the RPE verbal anchor that Parfit, Evans, and Eston (2012) observed to be a "pleasant and effective" intensity for training in previously sedentary people. The responses of breathing effort, reflected by the stages of the TT, will vary widely, and systematically, with the momentary intensity of exercise. Nominally, they will tell something about the sustainability of exercise at that intensity, and the likely effectiveness of that exercise intensity at provoking a training effect. As it turns out, they also tell quite a lot about physiology, within the 'threshold based' scheme of exercise evaluation and prescription recommended by Mezanni et al. (2012).

The body of evidence relative to the TT is substantial. Enough so that the procedure is recognized in the 10th edition of *ACSM's Guidelines for Exercise Testing and Prescription* (Riebe, 2017) and in the American Council on Exercise's *Personal Trainer Guide* (Foster & Porcari, 2010) as effective methods of guiding exercise training. The concept of the TT goes back at least until 1937, when Professor John Grayson advised mountaineers in Scotland to "climb no faster than you can talk" (Goode, 2008). While clearly not designed for exercise prescription, and acknowledging that the concept of the VT was still decades in the future (Hollmann, 1985; Wasserman & McIlroy, 1964), Grayson's advice recognized the fundamental truth that patterns of breathing and speech can give insight into the magnitude and sustainability of exercise intensity for a given task. Later studies, by Professor Goode in Toronto (Goode, Mertens, Shariman, & Mertens, 1998; Mertens, Bell, & Goode, 2001), suggested that the exercise intensity where people could first "hear themselves breathe", was associated both with heart rate (HR) guidelines and with an intensity approximating the VT.

During this same period of time, there were studies of the physiological responses during speech production. These studies demonstrated that speech required a suppression of breathing frequency. Typically, resting breathing frequency is ~15 times a minute, increasing up to 50-60 times a minute during a very heavy exercise. However, during speech, breathing frequency is markedly reduced, often to <10 times per minute at rest; and proportionately reduced during exercise. This reduction in breathing frequency leads to reductions in total ventilation, VO_2 and VCO_2 (Doust & Patrick, 1981; Meckel, Rotstein & Inbar, 2002; Rotstein, Meckel & Inbar, 2004). With these early studies suggesting changes in parameters that are central elements of the physiological response to exercise, the potential of the TT as a tool for exercise evaluation and prescription became obvious. Accordingly, there has been wide interest in the technique over the last 20 years.

This review is designed to collate the literature on the TT in a systematic way, to demonstrate what we know about the practical use of the TT, and to show some very recent data that further support the use of the TT.

Observational-correlative studies

In scientific inquiry, if a new measure is thought to be important, one of the first things to do is to observe how this new measure behaves, and to see if it correlates with measures of known importance. For example, if the Talk Test is revealing something important about exercise intensity, then its behavior should change with changes in exercise intensity, and it should be correlated with measures like %HRR, %VO_2max and ventilatory threshold (VT). Following the pioneering studies of Goode et al. (1998, 2008) and Mertens et al. (2001), contemporary interest in the TT began with preliminary reports from Henry Ford Hospital in Detroit. Brawner, Keteyian, & Czaplicki (1995) and Czaplicki, Keteyian, Brawner, & Weingarten (1997) presented evidence that exercisers, with speech driven by a questionnaire-based method, achieved values of HR that were within ACSM guidelines, during both treadmill ambulation and arm-leg cycle ergometry, just at the point where they no longer felt comfortable speaking. Reasoning that the suppression of breathing frequency required for speech production and the increase in both total ventilation and breathing frequency that naturally occur at the VT were incompatible, we and others have demonstrated that, when the exercise intensity was below the VT, speech was consistently rated as comfortable (e.g., "Yes, I can speak comfortably"). This has been labeled the Positive Stage of the TT (POS). As the exercise intensity approximated the VT, speech comfort is typically rated as equivocal (EQ) (e.g., "Yes, I can speak, but not entirely comfortably"). When exercise intensity meaningfully exceeded the VT, speaking ability was rated as definitely not-comfortable (NEG) (Dehart-Beverley, Foster, Porcari, Fater, & Mikat, 2000). Further observations have shown that the NEG stage of the TT occurs very close to the intensity at the RCT (Recalde, et al., 2002; Rodriguez-Marroyo, Villa, Garcia-Lopez, & Foster, 2013).

In many research settings in exercise science, the initial studies of any topic are done in young and healthy students, for both safety and convenience. Subsequent studies typically are performed to try to extend the range of populations where a new technique might be useful. Thus, early observations of the TT vs. VT/RCT relationship in young and healthy individuals have been extended to well-trained individuals (Foster, et al., 2012; Jeanes, Foster, Porcari, Gibson, & Doberstein, 2011; Recalde, et al., 2002; Woltmann, et al., 2015), to competitive athletes (Quinn, & Coons, 2011; Rodriguez-Marroyo, et al., 2013) and to patients with chronic disease (Brawner, et al., 2006; Cannon, et al., 2004; Cowan, Ginnity, Kressler, & Nash, 2012; Lyon, et al., 2014; Nielsen, et al., 2014; Petersen, Maribo, Hjortdal, & Lausten, 2014; Reed & Pipe, 2014; Voelker, et al., 2002; Zanettini, et al., 2013) (Figure 1). With the exception of children, of patients with heart failure, and of patients with respiratory disease (which have not been studied yet) it seems that if a person is speaking "comfortably", then the exercise intensity is less than the VT. At about the point where speech first becomes just less than fully comfortable, the intensity approaches that of the VT. And, at about the point where speech is first definitely not comfortable, the intensity approximates the RCT. Since the VT and RCT are powerful predictors of the sustainability of exercise (Foster & Cotter, 2005; Jones, Wilkerson, DiMenna, Fulford, & Poole, 2008), the simple measures provided by the TT may provide, in a very effective way, information that would otherwise be fairly complex to access (e.g., measured respiratory gas exchange).

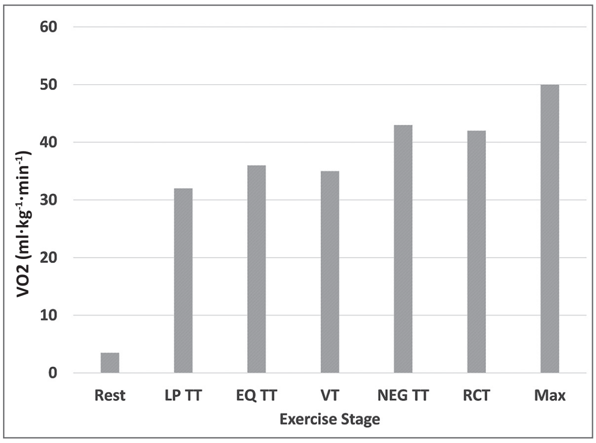

Figure 1. Schematic presentation of the relationship between distinct stages of the Talk Test (Last Positive = LP, Equivocal = EQ, and First Negative = NEG) in relation to the VT and RCT. Depending on the duration of the speech provoking stimulus, the LP stage usually slightly precedes the VT. The first NEG stage is often at an intensity just in excess of the RCT. Adapted from Dehart-Beverley et al. (2000) and Recalde et al. (2002).

The relationship between exercise intensity relative to physiological thresholds and the TT appears to be independent of the strategy for speech provocation. Studies using responses to a pre-recorded questionnaire (Brawner, et al., 1995, 2006; Czaplicki, et al., 1997), to reported speech comfort after reciting a standard paragraph (Dehart-Beverley, et al., 2000; Schafer, et al., 2000), to a counting task (Loose, et al., 2012; Norman, Hopkins, & Crappo, 2008) have demonstrated the robustness of the TT relative to manner of assessment. Indeed, a direct comparison of the pre-recorded questionnaire vs. the standard paragraph methods revealed no difference in the estimated VT (Brawner, et al., 2006). The TT technique is reliable in both healthy persons (Ballweg, et al., 2013) and patients with chronic diseases (Nielsen, et al., 2014), and appears to be robust relative to the type of ergometric assessment (Persinger, Foster, Gibson, Fater, & Porcari, 2004). Power output at standard markers of the TT is influenced by speech passage duration, with longer passages (~90 words) yielding lower values for VT and RCT, but also smaller prediction errors than shorter passages (~30 words) (Schroeder, Foster, Porcari, & Mikat, 2017) (Figure 2). Longer exercise stages (2-3 min vs. 1 min) yield smaller prediction errors than shorter exercise stages, as it appears that there needs to be a certain amount of recovery from the speech provoking stimulus, to allow a normal breathing pattern to occur before the TT is repeated (Xiong, Foster, Porcari, & Mikat, 2015) (Figure 3).

One of the large issues with exercise prescription, particularly for middle-aged and older individuals is the avoidance of exertional ischemia. Although exercise testing (Foster, 2017) and training (Foster, et al., 2008a) are generally very safe, there is ample evidence demonstrating that unaccustomed heavy exercise in previously sedentary individuals can trigger myocardial infarction and sudden death (Albert, et al., 2000; Mittleman, et al., 1993; Willich, et al., 1993) and that exercise-related catastrophes during cardiac rehabilitation programs are associated with exercise above the electrocardiographic ischemic threshold (Hassock & Hartwig, 1982). In studies where the TT was measured during incremental exercise testing, in patients who developed symptoms and ECG changes consistent with exertional ischemia, the last point where patients could speak comfortably (e.g., LP) was almost always (19/20 cases) prior to the first evidence of ECG

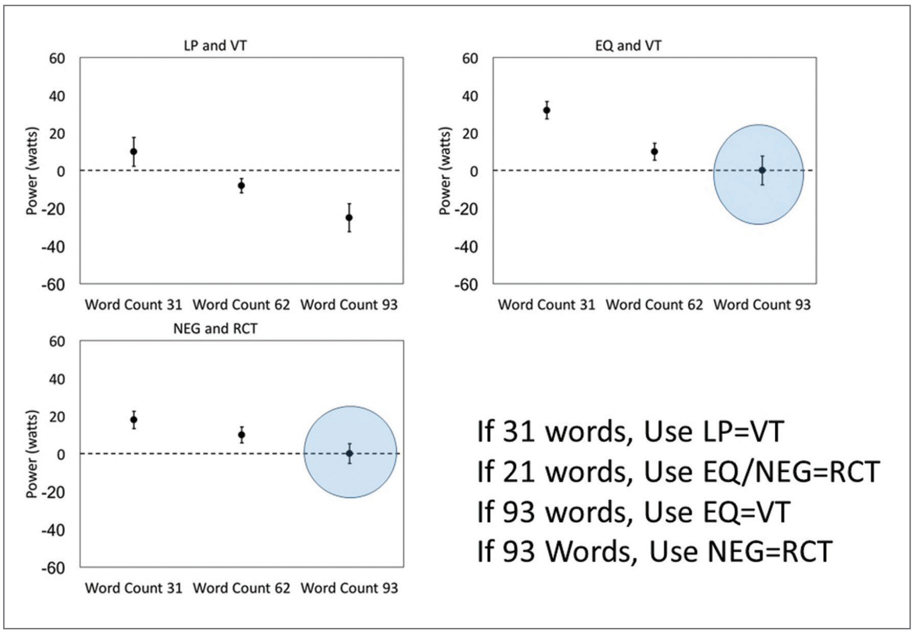

Figure 2. Errors in the estimation of the VT and the RCT based on the length of the speech provoking stimulus during the Talk Test. With longer speech passages (90-100 words), the EQ and NEG stages of the Talk Test produce very small errors relative to the VT and RCT, respectively. With short speech passages (~30 words), which are more user friendly, the VT occurs very close to the LP stage of the TT, and the RCT typically occurs between the EQ and NEG stages. Reprinted from Schroeder et al. (2017). With the use of intermediate length of speech passage duration (~60 words), the prediction errors were intermediate.

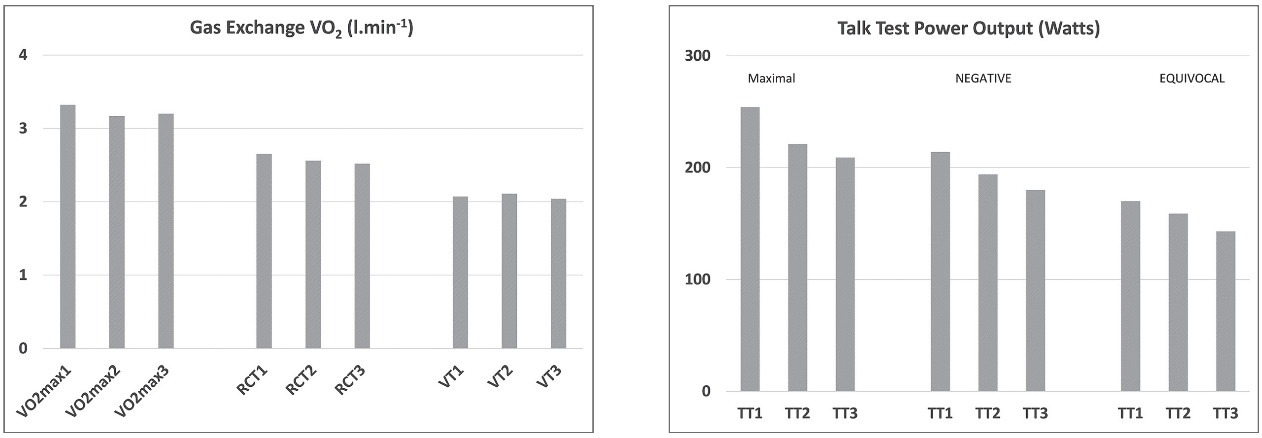

Figure 3. Regardless of the length of the exercise stage (1, 2, or 3 min), the VO_2 at the maximal exercise, at the VT and at the RCT remain constant (left pane). However, as stage duration increases, the power output at maximal exercise and at the NEG and EQ stages of the TT (i.e., surrogates of the VT and RCT) decreases steadily and significantly (right panel). This is likely due to the relative slowness of VO_2 kinetics, which during a rapidly incremented exercise allows exercise at higher power output before a critical VO_2 is reached. These data suggest that if one of the goals of exercise testing is to 'translate' exercise testing workloads into exercise training workloads, then relatively longer stages may be preferred.

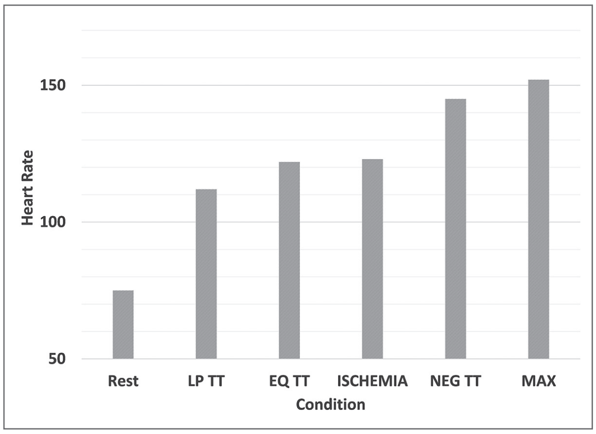

Figure 4. HR and Talk Test responses in patients who eventually develop ECG evidence of myocardial ischemia during exercise. The first ECG evidence of ischemia typically occurs just after the EQ stage of the Talk Test. The LP stage of the Talk Test is usually observed at a HR about 10 bpm below the first evidence of ischemia, which matches historical recommendations based on the maximal exercise vs. ECG responses. Avoidance of myocardial ischemia during exercise training predictably improves the safety of exercise training in patients with heart disease. Adapted from Cannon et al. (2004).

changes. Indeed, the last point where patients could speak comfortably was at a HR ~10 bpm below the HR at the first ECG evidence of ischemia (Cannon, et al., 2004). This 10 bpm HR 'buffer' is similar to that historically recommended for exercise training in patients with exertional ischemia (Riebe, 2017) (Figure 4).

Experimental studies

Provided that observational studies support the value of a new technique, the next normal step in scientific evaluation is to see if the new technique responds appropriately to experimental manipulation. Several experimental studies have been conducted for the purpose of validating the concepts and practice of the TT. Foster et al. (2008b) studied subjects performing stochastic exercise who performed the TT at the end of each 2-minute interval (Figure 5, upper left). Based on the power output during each interval, they predicted whether the subjects should be able to speak comfortably, based on riding at a power output that was either below or above the VT. They observed that in 73% of cases, the TT correctly predicted when the subjects were above or below VT (Figure 5, upper right). Most of the errors occurred when the power output was above VT (usually briefly) but the subjects were still able to speak comfortably. Follow up studies using square wave transitions from well below the VT to graduated intensities above the VT (105-120% of VT) indicated that at intensities just above the VT, it might take as much as four minutes to lose the ability to speak comfortably, but that at higher intensities (120-125% VT) speech became less than comfortable in as little as two minutes (Figure 5, lower left). These data demonstrated that there is a different response of the TT during incremental exercise and during transitions from easy exercise to exercise above VT (e.g., interval training). Foster et al. (2008b) also measured the relationship between changes in VT and the TT in subjects in whom VO_2max and VT were manipulated either by exercise training or by blood donation. The reciprocal changes in these markers of oxygen transport capacity in response to training and blood donation were well-matched by changes in the exercise intensity at the EQ stage of the TT (Figure 5, lower right). Thus, based on available evidence, it appears that the TT behaves as one would predict during experimental manipulations. The longer duration required to lose the ability to speak comfortably when exercise intensity is transitioned to just above the VT, compared to the apparently smoother transition during incremental exercise, remains to be explained. However, it seems clear that if comfortable speech is possible, that exercise intensity is, for the most part, below the intensity at VT.

Translational studies

One of the biggest problems for those guiding new exercisers, whether in the fitness industry or in clinical populations is to give really specific instructions about absolute exercise intensity, particularly during the first days and weeks of a training program. Given the health risk of exercising too hard too soon (Foster, et al., 2008a), and the compliance risk of very hard early exercise sessions, it is important to be able to recommend appropriate intensities at the very beginning of an exercise program. Historically, based on exercise test results, exercisers have been provided with a target HR range. However, by the time a beginning exerciser is able to get into an exercise bout and measure their HR, they may have already exceeded the target HR range, and be in a condition that is either unpleasant or dangerous. In the ideal world, responses during incremental exercise testing should be able to predict the absolute training intensity required to achieve a specified physiological response (% HRR, TT markers, blood lactate). In other words, one should be able to 'translate' exercise testing responses to give highly specific advice for exercise training, such as running pace or power output. Early studies (Foster, et al. 1986; Foster & Thompson, 1991; Foster, Thompson, & Bales, 1991) demonstrated that the duration during standard treadmill or arm-leg ergometer exercise tests at which target HR values were observed could be translated into either speed of level ground ambulation, power output, or even into defining when recreational activities were likely to produce heart rate responses within conventional guidelines (Foster & Thompson, 1991) (Figure 6). A similar approach has been

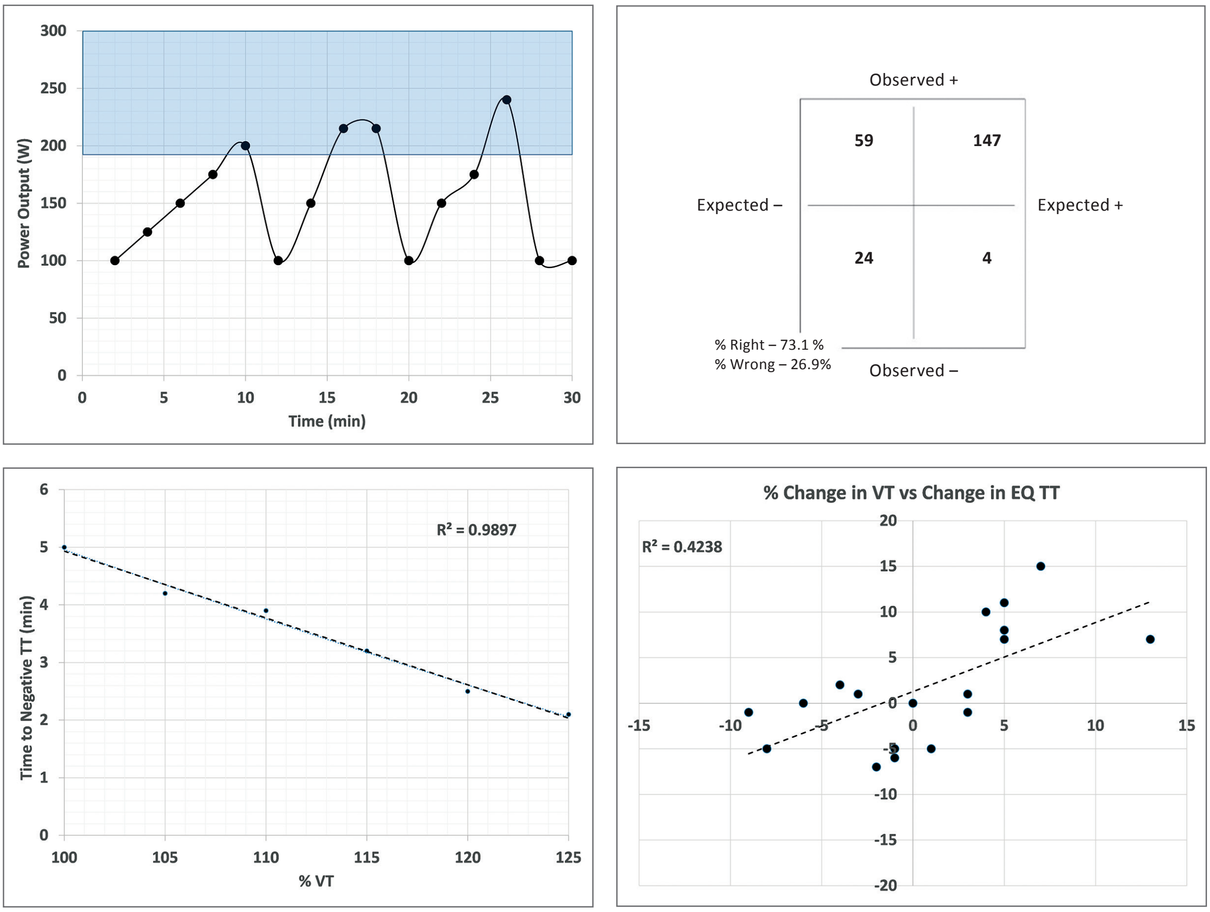

Figure 5. (Upper left) A schematic of power output (PO) during stochastic exercise to workloads above and below the VT. When PO exceeds the VT (shaded area), one predicts that comfortable speech will not be possible. (Upper right) Results of the TT responses during stochastic exercise. In 73% of cases the Talk Test response that was observed matched expectations. In 27% of cases the expected TT responses were discordant. Most of the discordant responses (59/63), involved the subject still being able to speak comfortably when they were predicted not to be able to speak comfortably. This is likely explained by (lower left) the 2-5 min required to lose the ability to speak comfortably during transitions from exercise well below the VT to above the VT. Experimental changes in the VT (based on either blood donation – lower left within figure, or exercise training – upper right within figure) (lower right) were well matched by changes in the workload at the EQ Talk Test (a surrogate for the VT workload). Adapted from Foster et al. (2008b).

applied using the TT. Using the intensity at the 'last positive'(LP) stage of the TT as a reference value, Jeanes et al. (2011), Foster et al. (2012), and Woltman et al. (2015) have shown that in well-trained individuals, this speed/power output can be sustained comfortably, without undue drift in HR, blood lactate or TT responses. In sedentary adults, the prior stage of the TT, "LP-1", seems to be an appropriate intensity for comfortable steady state exercise (Foster, et al., 2009), and LP-2 appears to work best for patients in cardiac rehabilitation programs (Lyon, et al., 2014). Thus, based on a simple, submaximal exercise test, with further increments in workload stopped at the point where speech is first less than fully comfortable, the equivocal (EQ) stage of the TT, one can choose reasonable absolute workloads for steady state training in populations ranging from cardiac patients to athletes. Although the smallest error in predicting VT is achieved using longer (3 min) stages (Xiong, et al, 2015) and longer (~100 word) speech passages (Schroeder, et al., 2017), it seems likely that most people are going to use shorter (~30 words) speech passages, because it is more convenient and does not require a cue card. In this case, the EQ stage achieved during an incremental test is likely to be non-sustainable during exercise training. Further, if one wants to train at intensities approximating or exceeding the maximal lactate steady state (MLSS) in athletes, reasonable candidate workloads can be individually selected from responses at the first negative (NEG) stage during a submaximal exercise test with the TT (Rodriguez-Marroyo, et al., 2013; Woltmann, et al., 2015). During sustained steady state exercise, at the intensity of the MLSS, the EQ stage of the TT is usually observed (Foster, Kohlman, Smith, & Porcari, 2017b). Of course, any of the translated workloads must be evaluated as the training session progresses, but given the need to pick appropriate intensities for the first workout, responses during the TT can suggest reasonable absolute starting intensities.

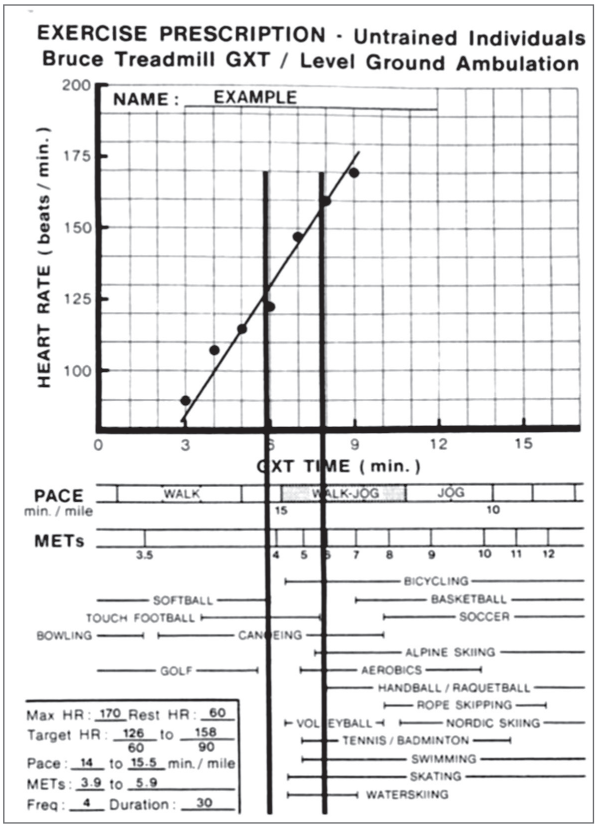

Figure 6. A schematic of plan for translating standard exercise test responses (Bruce treadmill protocol) based on HR responses during the test. The HR response is plotted and smoothed, and the time during the exercise test that target HR, based on Karvonen calculations, is defined. From this target HR time, a speed for level ground ambulation can be computed from the algorithm built into the figure. Given the strong relationship between the speed of level ground ambulation and the MET cost of activity, the likelihood that several commonly played sports activities will produce desired values for training HR can be estimated. Adapted from Foster et al. (1986, 1991a, 1991b).

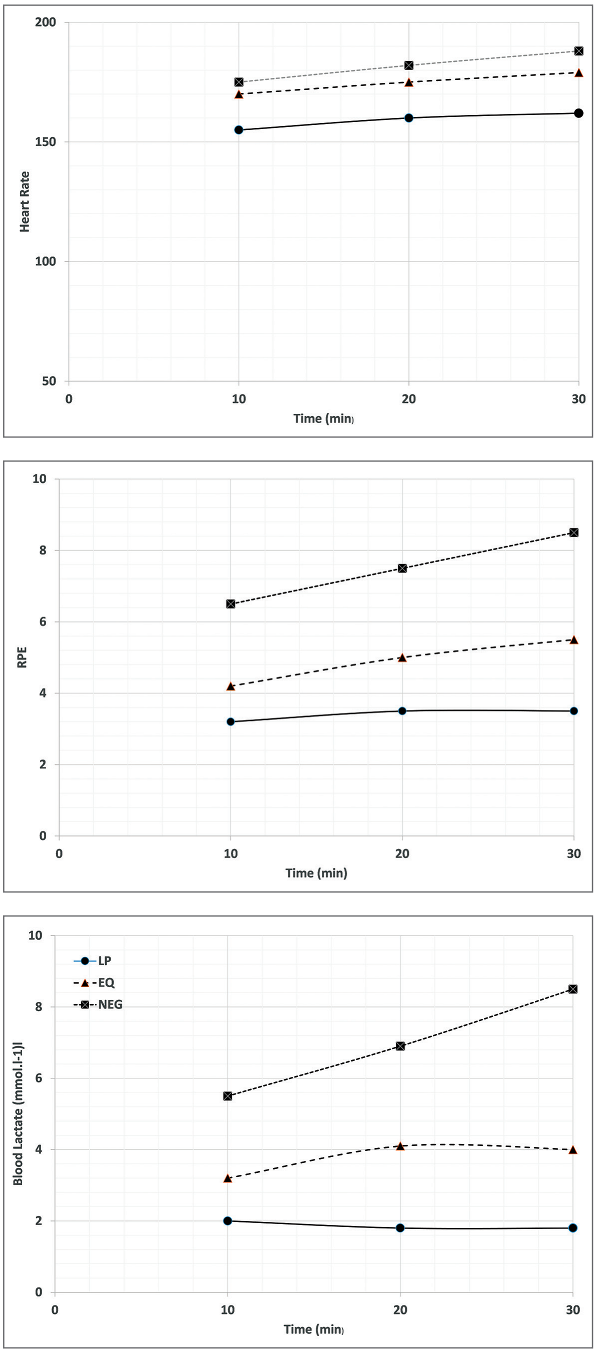

Figure 7. Responses of HR (upper), RPE (middle) and blood lactate (lower) during 30 min of near steady state exercise, when the running speed was manipulated to preserve Talk Test responses in the POS, EQ, or NEG stages of the Talk Test. Steady state running at the POS stage of the Talk Test is well-tolerated, with low RPE and blood lactate. Running at the EQ stage is comparable to steady state exercise near the MLSS intensity. When running speed is in the NEG stage of the Talk Test, the intensity is higher than that of the MLSS. Adapted from Woltmann et al. (2015).

Physiological mechanisms

Given how well the TT works relative to identifying physiological threshold events and workloads for training, it is reasonable to ask how it works. Early work (Doust & Patrick, 1981; Meckel, Rotstein, & Inbar, 2002; Rotstein, Meckel, & Inbar, 2004) suggested that breathing frequency was suppressed during speech, secondary to a need to allow for reasonable speech patterns. This led to reductions in total ventilation, VO_2 and VCO_2, and to a slight increase in blood lactate concentration during speech. While physiological systems are well integrated to allow for continued ATP generation in the presence of brief reductions in VO_2, there is no reasonable strategy for dealing with a reduction in VCO_2, as even small increases in P_aCO_2 lead to large increases in the drive to breathe (Wasserman, et al., 2011). Creemers, Foster, Porcari, Cress, & de Koning (2017) have recently evaluated gas exchange responses during the TT at intensities where speech was comfortable (e.g., LP stage) and as speech became progressively less comfortable (EQ and NEG stages), they demonstrated that total ventilation, breathing frequency, VO_2 and VCO_2 were progressively reduced during speech as exercise intensity was incremented. Uniquely, they also demonstrated that there was a progressive increase in $P_{et}CO_2$ (a

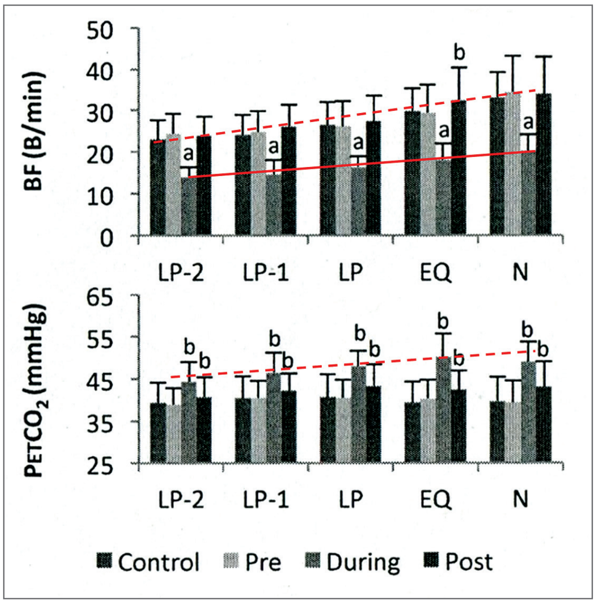

Figure 8. Changes in breathing frequency and $P_{et}CO_2$ (a surrogate of P_aCO_2) in relation to the stages of the TT. Note that the BF normally increases progressively with intensity, and that this allows, in the control (non-speaking) trial for $P_{et}CO_2$ to remain constant despite a progressively larger VCO_2. The same results are observed during the speaking trial before the speech passage (Pre). During the execution of the speech passage, the BF decreases significantly at all workloads and during the speech passage the $P_{et}CO_2$ increases significantly at all workloads. After the conclusion of the speech passage (Post), the BF and $P_{et}CO_2$ return to normal. However, in the speaking trial, the systematic decrease in BF is associated with (indeed probably causes) progressive increases in $P_{et}CO_2$, even before the EQ and NEG stages of the Talk Test are achieved. The magnitude of the associated CO_2 trapping with speech is large enough that the $P_{et}CO_2$ is still not fully recovered to control levels even 15 s after speaking has terminated.

surrogate of P_aCO_2) during speech with increases in exercise intensity. Given that P_aCO_2 and $P_{et}CO_2$ are normally downregulated as exercise intensity increases beyond the VT (Wasserman, et al., 2011), the progressive increase in $P_{et}CO_2$ during the TT is consistent with an increased drive to breathe, and likely to reductions in speech comfort. Further, these data are consistent with the decrease in power output at convenient markers of TT performance (e.g., the LP, EQ and NEG stages) as speech passages increase in duration (Schroeder, et al., 2017) (Figure 8). Although not tested directly, it is reasonable to speculate that as the duration of reduced ventilation increases (e.g., due to longer speech passages), $P_{et}CO_2$ will increase to a larger degree. Given the striking increase in VCO_2 that normally occurs at both the VT and RCT, interference with CO_2 elimination by speaking would likely amplify the normal respiratory signaling at these intensities.

Contemporary findings

The hypothesis that stages of the TT are reasonable surrogates of physiological threshold events seems to be well supported, from a number of sources, ranging from athletes to patients with chronic diseases. There are a variety of new findings that add further support to this hypothesis. The first is that simply by asking people to exercise at an intensity that "just allows comfortable speech" successfully guides exercisers to intensities that are within ACSM guidelines for %maxMETs, % $HR_{reserve}$ and RPE (Porcari, et al., 2016). Further, exercise guided by the simple instruction to "keep speech comfortable" is associated with blood lactate responses consistent with physiological steady state conditions (<2.5 mmol·l^{-1}). To demonstrate this, either healthy untrained individuals or patients enrolled in a cardiac rehabilitation program performed maximal incremental exercise (to establish reference values for HR and RPE for research comparison). They also performed a submaximal incremental test, stopping at the EQ stage of the TT. On another day, they began walking at a very comfortable pace (LP-2), while reciting a standard 101-word paragraph every 2 min. If they were comfortable speaking, the grade on the treadmill belt was increased by a small increment (1-2%). When speech was no longer fully comfortable (EQ stage), the grade on the treadmill belt was decreased progressively until comfortable speech was regained. Within 15 min, all subjects had achieved stable values for speech comfort, and stable values for %HRR, RPE and blood lactate (Figure 9). These results demonstrate that even without exercise testing, which was only used as a method of reference in this study, the TT can guide exercise training intensity into reasonable zones in the individuals who most need guidance (sedentary people, patients with chronic diseases), simply by instructing them to adjust their walking intensity to the highest level compatible with comfortable speech.

Endurance athletes are often encouraged to do much of their high intensity training either at the intensity of the maximal lactate steady state (Beneke & von Duvillard, 1996) or in the range between MLSS and VO_2max (Billat, et al., 1999). The MLSS is widely thought to approximate the intensity of the RCT, which during incremental exercise is associated with the first NEG stage of the TT. However, our knowledge of the need to 'step down' intensities from exercise testing to achieve successful translation during steady state exercise suggests that a lower intensity might be necessary. To address this problem (Foster, et al., 2017b), well-trained cyclists/triathletes performed both incremental exercise testing and several 30-minute steady state submaximal rides, to allow definition of the MLSS. Sustained exercise, at the intensity associated with the LP stage of the TT, produced stable conditions consistent with MLSS (a stable lactate value between 10 and 30 min, with a blood lactate concentration of 4-5 mmol·l^{-1}, HR in the range of 70-80%

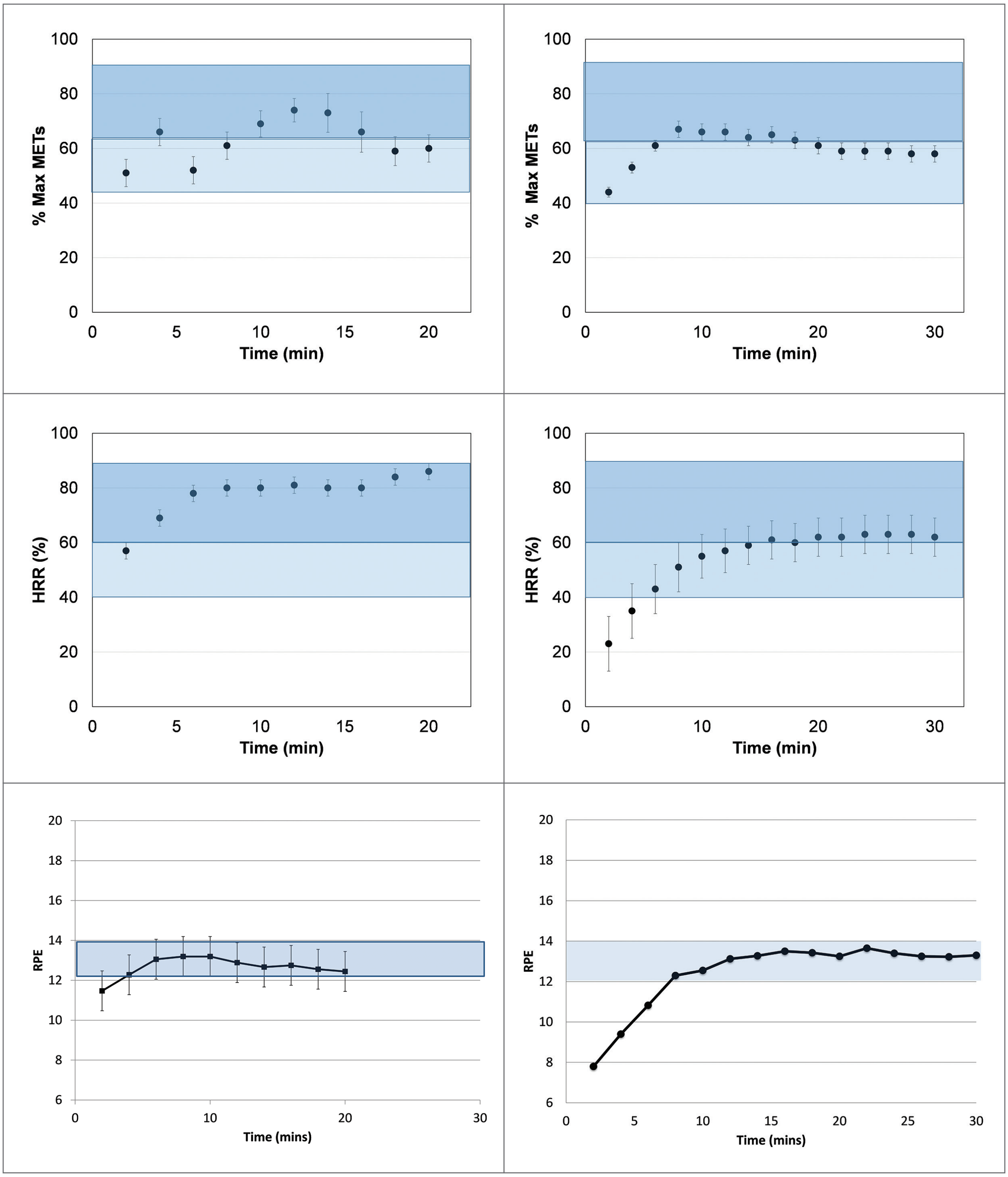

Figure 9. Changes in relative exercise intensity (% maximal METs – top, and %HRR – middle) and RPE (bottom) during 20-30 min of exercise training in cardiac patients (left pannels) and healthy, sedentary individuals (right pannels). Exercise began at a very comfortable pace and was incremented every 2 min until the EQ stage of the Talk Test was achieved. Then, the exercise intensity was decreased until the POS stage of the Talk Test was regained. For the remainder of the exercise bout, small changes in treadmill grade were made to ensure that speaking remained in the POS stage for speech comfort. The results demonstrate that in these two vulnerable populations, who would normally most need guidance from an exercise test, a pace that 'just allows comfortable speech' produces physiological and perceptual responses that are within ACSM guidelines (shaded areas). Adapted from Porcari et al. (2016).

HRR, RPE in the range of 5-6, and speech responses equivalent to the EQ stage of the TT) (Figure 10). These data suggest that findings of earlier studies indicating that the EQ TT stage during incremental exercise (Foster, et al., 2012; Jeans, et al., 2011; Woltmann, et al. 2015) may have been unreasonably optimistic. Together with the observation that there may be a delay in establishing steady state speaking conditions at intensities just above the ventilatory threshold (Foster, et al., 2008b) and that there

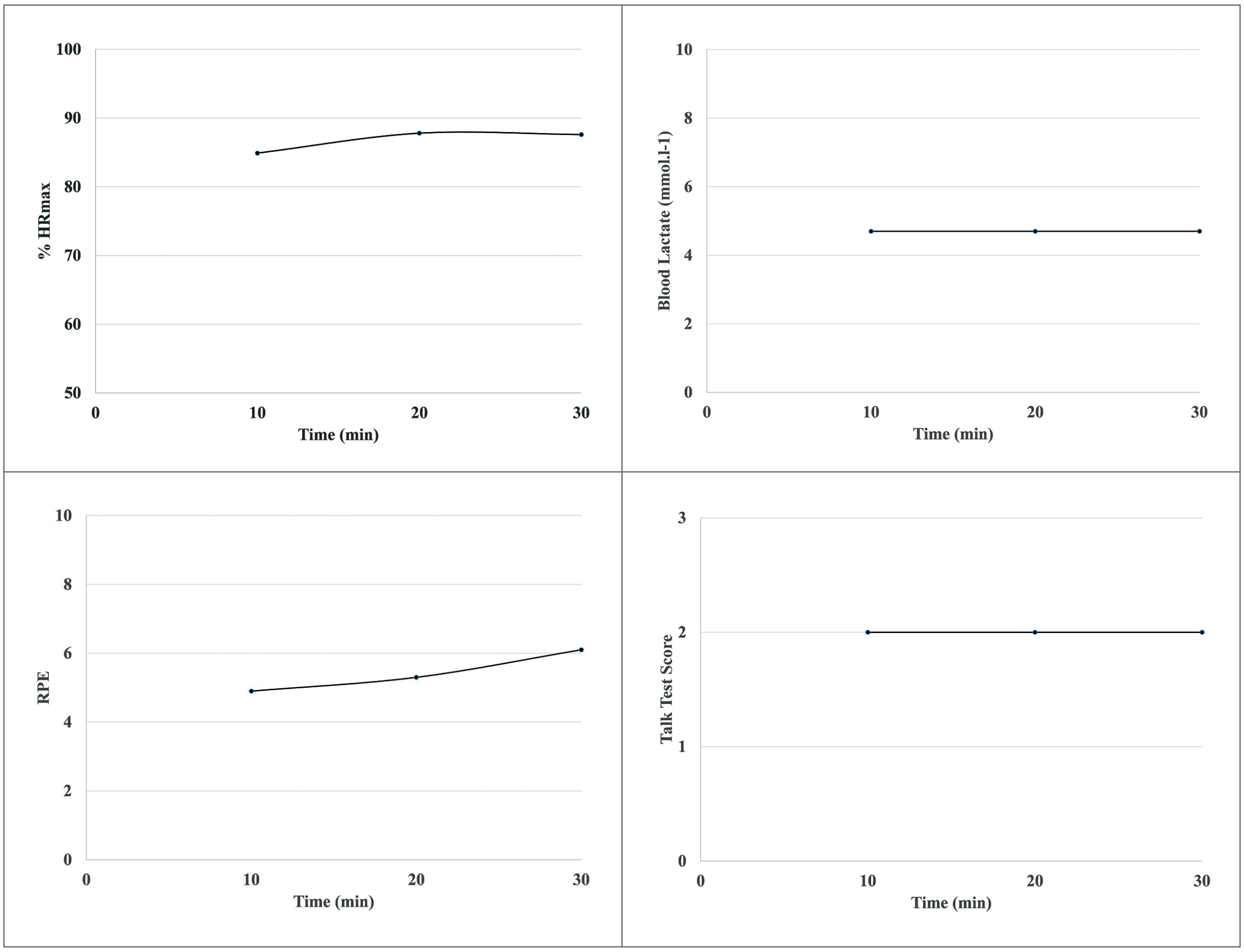

Figure 10. Responses during 30 min steady state rides in cyclists/triathletes, during workloads that matched conditions for MLSS (< 1 mmol·l^-1 change in blood lactate between 10 and 30 min). Each subject performed multiple rides to establish MLSS. During the MLSS ride, the HR was stable in the range of 75-80 %HRR, RPE was nearly stable in the range of 5-6 and blood lactate was stable at 4-5 mmol·l^-1. During this period of time, speech comfort was consistently rated at the EQ stage (e.g., 'I can speak comfortably, but it's getting harder'). Adapted from Foster et al. (2017b).

may already be increases of the $P_{et}CO_2$ even at intensities below the EQ stage of the TT (Schroeder, et al., 2017), these results suggest that conservative approaches to translating incremental Talk Test responses may be preferred. This idea is particularly important when one remembers that the LP stage of the TT is probably more closely associated with the VT if short (~30 word) speech provoking stimuli are used.

The TT, like any other method of exercise prescription, is grounded in its ability to guide exercise training intensity in a way that produces predictable changes in exercise capacity, particularly VO_2max (Garber, et al. 2011; Pollock, 1973; Riebe 2017). Guidance of exercise intensity using %HRR goes back more than 60 years (Karvonen, Kentala, & Mustala, 1957) and the effectiveness of the method was well-established more than 40 years ago (Pollock, 1973). More recent data, using RPE as a direct guide to exercise training intensity, have demonstrated that simple, subjective methods may guide training in a way to produce predictable changes in VO_2max and VT (Parfitt, Evans, & Eston, 2012). Recent data, from a randomized trial, of a direct comparison between the TT and %HRR as tools for guiding exercise training are available (Porcari, et al., 2018) (Figure 11). These data demonstrate that the observational and experimental evidence of the potential effectiveness of the TT as a guide for exercise training are correct. They, together with other data presented here (Figure 9), further demonstrate that the TT allows exercise training to be effectively guided even without the necessity of a preliminary exercise test.

Practical applications

A schematic example of how an exercise, test using the TT, might proceed is presented in Figure 12. The test should begin at a very comfortable workload (~20-25 Watts) and be incremented in modest (~20-25 Watts) stages every 3 minutes. In more debilitated individuals, such as patients with chronic diseases, the starting point and increment size can be smaller (10-15 Watts). Before exercise

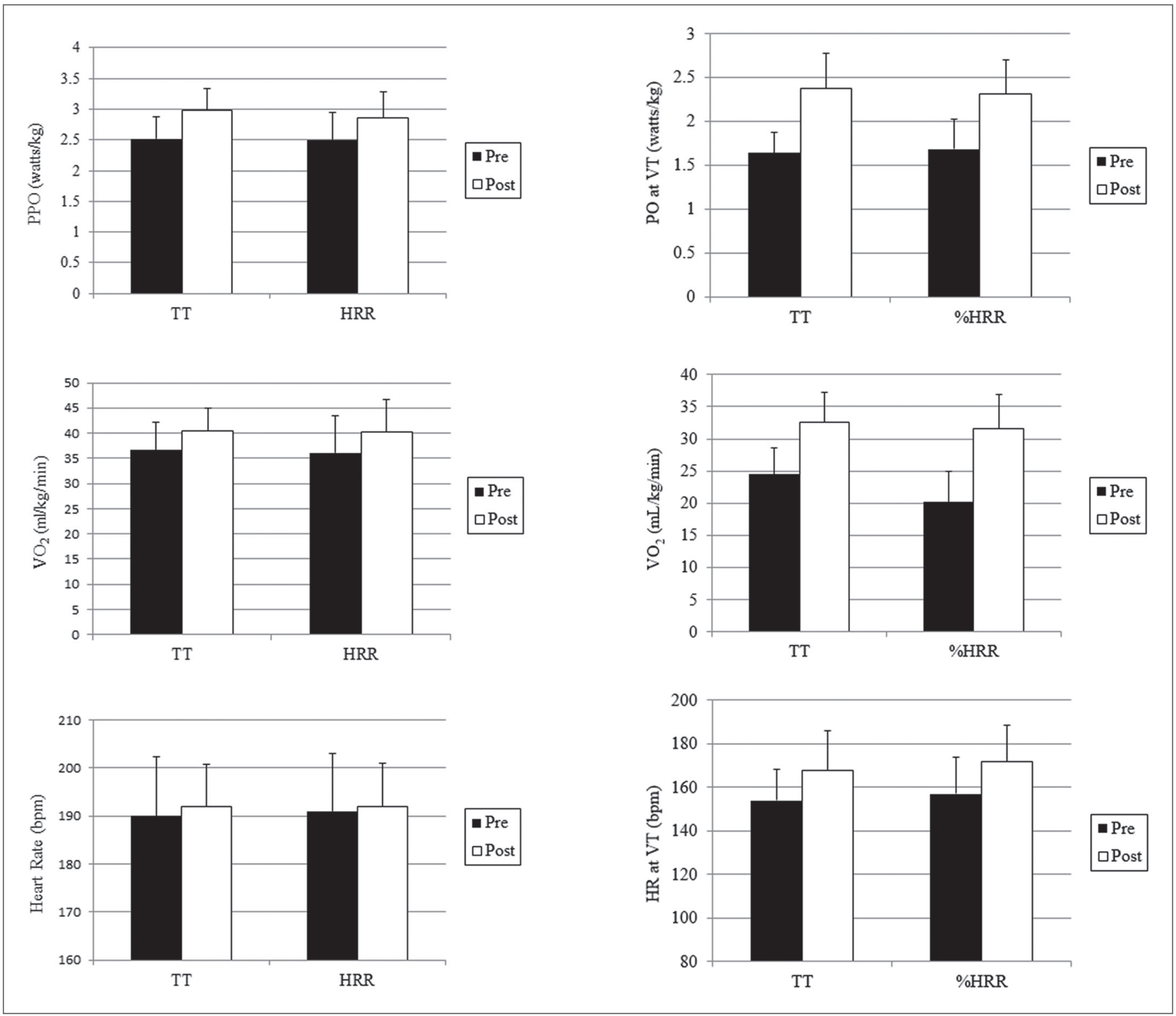

Figure 11. Changes in power output (top), VO_2 (middle) and HR (bottom) resulting from training in healthy, sedentary people during the maximal exercise (left) and at the VT (right) consequent to a 10-week training program that was guided using either the Talk Test (maintaining the LP stage as closely as possible) or %HRR using the ACSM guidelines and scheme of progression (Riebe, 2017). Without the need for a preliminary exercise test, the TT was able to successfully guide the subjects in the Talk Test group to equivalent improvement in the %HRR reserve group (which required a preliminary maximal exercise test). Reprinted from Porcari et al. (2018).

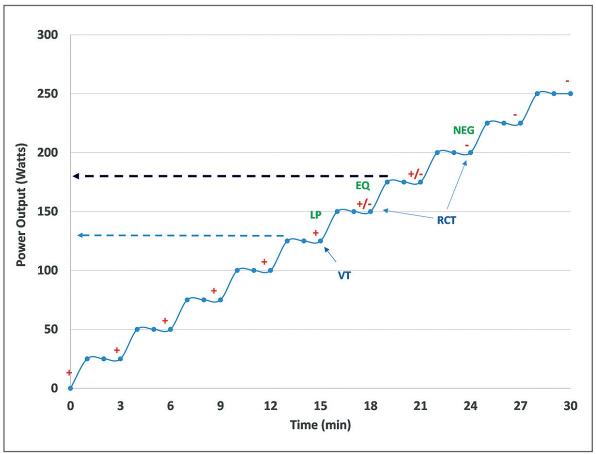

Figure 12. A schematic of a simple practical approach to using the Talk Test during incremental exercise. The test begins at 25 Watts, and is incremented 25 Watts every 3 min. During the last 30 seconds of each stage the Talk Test is performed using a short (~30 word) speech passage, after which HR and RPE are recorded. The VT most likely occurs at the LP stage of the Talk Test, and the RCT most likely occurs in the space between the EQ and NEG stages of the Talk Test. If it is desirable to measure maximal exercise capacity, the test can be continued until fatigue. However, for both the assessment and exercise prescription, the test can be terminated at either the EQ or NEG stages of the Talk Test. In most fit/athletic individuals a reasonable starting workload for steady state training is at the LP stage, as the intensity will 'drift' toward the EQ stage as exercise is continued. For more sedentary individuals, the LP-1 is a reasonable starting intensity, and for very unfit individuals and/or patients with chronic diseases, the LP-2 stage is often appropriate for starting a training program.

and during the last 30 seconds of each stage, the subject should recite a standard paragraph out loud. Although longer passages, 90-100 words, are likely to give more precise results (Schroeder, et al. 2017), shortened (~30 words) paragraphs such as "The Pledge of Allegience", which is widely known to most people in the U.S., are probably more user friendly and may be substituted. With longer speech provoking passages, the first EQ stage of the TT is likely at an intensity approximating the VT, and the first NEG stage of the TT likely approximates the RCT. If a shorter passage is preferred, the LP stage is probably closer to the VT, and the RCT is likely between the EQ and NEG stages. If one wants to assess maximal exercise capacity, the test may, of course, be continued until fatigue. However, from the practical standpoint of assessing convenient markers of exercise capacity to allow tracking of changes in exercise capacity and to prescribe exercise, the test can be functionally completed by the time the first EQ or NEG stage is achieved. For most sedentary individuals, the LP-1 or LP-2 stages are probably useful starting points for exercise prescription. For already trained individuals, the LP or EQ stages are good candidates for steady state training.

Summary

The TT appears to represent a promising subjective method of both exercise testing, particularly for estimating the VT and RCT, and for defining workloads that are appropriate for exercise training. From a practical standpoint, reciting paragraphs of ~30 words, out loud, and responding to the question "Can you speak comfortably?" will yield distinct stages of response…..POS, EQ, NEG. However, other methods of speech provocation (e.g., responding to standard questions or counting) are also likely to be useful, as the TT technique appears to be robust. Under these circumstances, the LP stage is most likely related to the VT, and the stage between the EQ and NEG stages is most likely related to the RCT. If one wants more precision, using longer speech provoking passages (~100 words) is preferred. In this variant, the EQ and NEG stages are well related to the VT and RCT, respectively.

For prescribing exercise, as a general principle, one incremental TT stage down from where the VT is believed to be is a reasonable starting workload for most people. In particularly sedentary individuals or in patients with chronic disease, 2 stages down from the anticipated workload at the VT is likely to be most appropriate. As long as individuals can maintain comfortable speech during exercise, they are unlikely to have myocardial ischemia, even if they are capable of developing it during heavier exercise. Given the linkage between exertional ischemia and catastrophic events during exercise, this feature of the TT is particularly appealing. The best current evidence is that the TT works equally well across a broad range of populations from competitive athletes to patients with chronic diseases and is robust across modes of exercise, although it has only been directly compared for walking/running vs. cycling. Thus, based on the available evidence, the TT appears to be a useful subjective method of exercise evaluation and prescription, essentially co-equal to RPE. As such, it may open doors to guiding exercise programming that formerly were dependent on the availability of exercise test results.

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