KEY CONCEPT

VENTILATORY THRESHOLD TESTING

Ventilatory threshold testing is based on the physiological principle of ventilation. During submaximal exercise, ventilation increases linearly with oxygen consumption and carbon dioxide production. This occurs primarily through an increase in **tidal volume** (i.e., the volume of air inhaled and exhaled per breath). At higher or near-maximal intensities, the frequency of breathing becomes more pronounced and **minute ventilation ($\dot{V}_E$)** (measured as the volume of air breathed per minute) rises disproportionately to the increase in oxygen consumption (Figure 1).

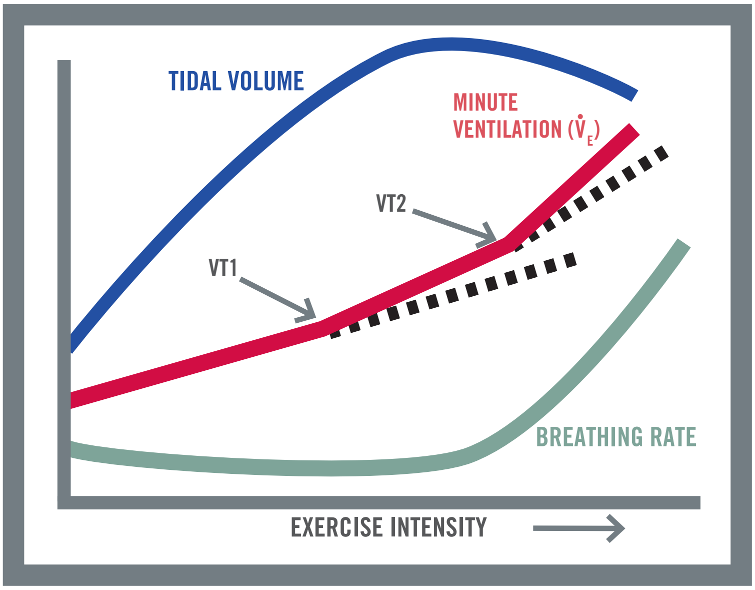

Figure 1
Ventilatory effects during aerobic exercise

Note: VT1 = First ventilatory threshold; VT2 = Second ventilatory threshold

This disproportionate rise in breathing rate represents a state of ventilation that is no longer directly linked with oxygen demand at the cellular level and is generally termed the ventilatory threshold. The overcompensation in breathing frequency results from an increase in carbon dioxide (CO_2) output related to the **anaerobic glycolysis** that predominates during near-maximal-intensity exercise. During strenuous exercise, breathing frequency may increase from 12 to 15 breaths per minute at rest to 35 to 45 breaths per minute, while tidal volume increases from resting values of 0.4 to 1.0 L up to 3 L or greater (McArdle, Katch, & Katch, 2010).

As exercise intensity increases, ventilation increases in a somewhat linear manner, demonstrating deflection points at certain intensities associated with metabolic changes within the body. One point, called the "crossover" point, or the **first ventilatory threshold (VT1),** represents a level of intensity blood lactate accumulates faster than it can be cleared, which causes the person to breathe faster in an effort to blow off the extra CO_2 produced by the buffering of acid metabolites. Prior to this intensity, fats are a major fuel and only small amounts of lactate are being produced. The cardiorespiratory challenge to the body lies with **inspiration** and not with the **expiration** of additional amounts of CO_2 (associated with buffering lactate in the blood). The need for oxygen is met primarily through an increase in tidal volume and not respiratory rate. Past the crossover point, however, ventilation rates begin to increase exponentially as oxygen demands outpace the oxygen-delivery system and lactate begins to accumulate in the blood. Consequently, respiratory rates increase.

The second disproportionate increase in ventilation—the **second ventilatory threshold (VT2),** sometimes called the **respiratory compensation threshold (RCT)**—occurs at the point where lactate is rapidly increasing with intensity, and represents hyperventilation even relative to the extra CO_2 that is being produced. It probably represents the point at which blowing off the CO_2 is no longer adequate to buffer the increase in acidity that is occurring with progressively intense exercise.

In well-trained individuals, VT1 is approximately the highest intensity that can be sustained for one to two hours of exercise. In elite marathon runners, VT1 is very close to their competitive pace. The VT2 is the highest intensity that can be sustained for 30 to 60 minutes in well-trained individuals.

An important note for testing purposes is that the exercise intensity associated with the ability to talk comfortably is highly related to VT1. As long as the exerciser can speak comfortably, he or she is almost always below VT1. The first point where it becomes more difficult to speak approximates the intensity of VT1, and the point at which speaking is definitely not comfortable approximates the intensity of VT2. Refer to Chapter 11 for more information on how to apply the VT1 and VT2 to exercise programming.

Some trainers may have access to metabolic analyzers that will allow them to identify VT1 and the VT2 using the **respiratory exchange ratio (RER)** scores (approximately 0.85 to 0.87 for VT1 and approximately 1.00 for VT2). However, the majority of trainers will not have access to metabolic analyzers and will need valid field tests to identify these markers. This section reviews field tests for measuring HR at VT1 and VT2.

Contraindications

This type of testing is not recommended for:

- Individuals with certain breathing problems [**asthma** or other **chronic obstructive pulmonary disease (COPD)**]
- Individuals prone to panic/anxiety attacks, as the labored breathing may create discomfort or precipitate an attack
- Those recovering from a recent respiratory infection

Submaximal Talk Test for VT1

This test is best performed using HR **telemetry** (HR strap and watch) for continuous monitoring. To avoid missing VT1, the exercise increments need to be small, increasing steady-state HR by approximately 5 bpm per stage. Consequently, this test will require some preparation to determine the appropriate increments that elicit a 5 bpm increase (0.5 mph, 1% incline, or one to two levels on a bike/elliptical trainer are typical). Once the increments are determined, the time needed to reach steady-state HR during a stage must also be determined (60 to 120 seconds per stage is usually adequate).

The end-point of the test is not a predetermined heart rate, but is based on monitoring changes in breathing rate (technically metabolic changes) that are determined by the client's ability to recite a predetermined combination of phrases. *Note:* Reading as opposed to reciting from memory may not be advised if it compromises balance on a treadmill.

The objectives of the test are to measure the HR response at VT1 by progressively increasing exercise intensity and achieving steady state at each stage, as well as to identify the HR where the ability to talk continuously becomes compromised. This point represents the intensity where the individual can continue to talk while breathing with minimal discomfort and reflects an associated increase in tidal volume that should not compromise breathing rate or the ability to talk. Progressing beyond this point where breathing rate increases significantly, making continuous talking difficult, is not necessary and will render the test inaccurate.

Equipment:

- Treadmill, cycle ergometer, elliptical trainer, or arm ergometer
- Stopwatch
- HR monitor with chest strap (optional)
- Cue cards, if needed; any 90-word statement will do (such as the Pledge of Allegiance recited three times consecutively)

Pre-test procedure:

- As this test involves small, incremental increases in intensity specific to each individual, the testing stages need to be predetermined. The goal is to incrementally increase workload in small quantities to determine VT1. Large incremental increases may result in the individual passing through VT1, thereby invalidating the test:

    - ✓ Recommended workload increases are approximately 0.5 mph, 1% grade, or 15 to 20 watts.
    - ✓ The objective is to increase HRss at each stage by approximately 5 bpm.
    - ✓ Plan to complete this test within eight to 16 minutes to ensure HRss is achieved at each stage. The trainer should progress the client so that localized muscle fatigue from longer durations of exercise is not an influencing factor.
- Measure pre-exercise HR and BP (if necessary), both sitting and standing, and then record the values on the testing form.
- Describe the purpose of this graded exercise test, review the predetermined protocol, and allow the client the opportunity to address any questions or concerns. Each stage of the test lasts one to two minutes to achieve HRss at each workload.
- Toward the latter part of each stage (i.e., last 20 to 30 seconds), measure the HR and then ask the client to recite the Pledge of Allegiance three times or another predetermined passage or combination of phrases. The client's ability to talk without difficulty will be evaluated.
    - ✓ When fats are the primary fuel (below VT1), the demand for O_2 is met by increasing tidal volume. Therefore, the ability to talk continuously during expiration should not be compromised. This implies taking a noticeably deeper breath every five to 10 words, but not gasping due to the increased breathing rate.
    - ✓ However, when carbohydrates become the primary fuel (above VT1) the demand for CO_2 removal is met by increasing breathing rate. Therefore, the ability to talk continuously during expiration becomes compromised. This implies a noticeable increase in breathing rate where the ability to string five to 10 words together becomes challenging or difficult.
- Conversations with questions and answers are not suggested, as the test needs to evaluate the challenge of talking continuously, not in brief bursts as in conversation.
- Allow the client to walk on the treadmill or use the ergometer to warm up and get used to the apparatus. If using a treadmill, he or she should avoid holding the handrails. If the client is too unstable without holding onto the rails, consider using another testing modality, as this will invalidate the test results.
- Take the client through a light warm-up (2- to 3-out-of-10 effort) for three to five minutes, maintaining a heart rate below 120 bpm.

Test protocol and administration:

- Once the client has warmed up, adjust the workload intensity so the client's HR is approximately 120 bpm, or an intensity level of 3 to 4 on a 10-point scale.
- Begin the test, maintaining the intensity until HRss is achieved. Record this value.
- Ask the client to recite something from memory or read aloud continuously for 20 to 30 seconds.
    - ✓ Trainers should exercise caution if deciding to ask a client to read something while using a treadmill, given the potential risk of falling.
- Upon completion of the recital or reading, ask the client to identify whether he or she felt this task was easy, uncomfortable-to-challenging, or difficult.
- If VT1 is not achieved, progress through the successive stages, repeating the protocol at each stage until VT1 is reached.
- Once the HR at VT1 is identified, progress to the cool-down phase (matching the warm-up intensity) for three to five minutes.
- This test should ideally be conducted on two separate occasions with the same exercise modality to determine an average VT1 HR.
    - ✓ HR varies between treadmills, bikes, etc., so it is important to conduct the tests with the exercise modality that the client uses most frequently.
    - ✓ The VT1 HR will also be noticeably higher if the test is conducted after weight training due to fatigue and increased metabolism. Therefore, clients should be tested before performing resistance-training exercises.

APPLY WHAT YOU KNOW

APPLYING THE RESULTS OF THE TALK TEST FOR VT1 The HR at VT1 can now be used as a target HR when determining exercise intensity. Those interested in sports conditioning and/or competition would benefit from training at higher intensities, but those interested in health and general fitness are well-served to stay at or slightly below this exercise intensity.

VT2 Threshold Test

VT2 is equivalent to another important metabolic marker called the **onset of blood lactate accumulation (OBLA),** the point at which blood lactate accumulates at rates faster than the body can buffer and remove it (blood lactate >4 mmol/L). This marker represents an exponential increase in the concentration of blood lactate, indicating an exercise intensity that can no longer be sustained for long periods, and represents the highest sustainable level of exercise intensity, a strong marker of exercise performance. Continually measuring blood lactate is an accurate method to determine OBLA and the corresponding VT2. However, the cost of lactate analyzers and handling of biohazardous materials make it impractical for most fitness professionals. Consequently, field tests have been created to challenge an individual's ability to sustain high intensities of exercise for a predetermined duration to *estimate* VT2. This method of testing requires an individual to sustain the highest intensity possible during a single bout of steady-state exercise. This obviously mandates high levels of conditioning and experience in pacing. Consequently, VT2 testing is *only* recommended for well-conditioned individuals with performance goals.

While laboratory testing (collecting blood samples) represents the most accurate method to assess OBLA, limitations related to accessibility, equipment, technical expertise, cost, and functional application render this unfeasible in most cases. Consequently, field tests are commonly used to identify the HR response associated with VT2. The major disadvantages associated with field tests are that they do not assess any direct metabolic responses beyond heart rate and that they can be influenced by environmental variables (e.g., temperature, humidity, and wind) that may potentially impact the accuracy of the numbers obtained. While several laboratory protocols have been validated through research over the past 30 years, relatively little research has evaluated or validated field-testing protocols.

Well-trained individuals can probably estimate their own HR response at VT2 during their training by identifying the highest sustainable intensity they can maintain for an extended duration. In cycling, coaches often select a 10-mile time trial or 60 minutes of sustained intensity, whereas in running, a 30-minute run is often used. Given that testing for 30 to 60 minutes is impractical in most fitness facilities, trainers can opt to use shorter single-stage tests of highest sustainable intensity to estimate the HR response at VT2.

In general, the intensity that can be sustained for 15 to 20 minutes is higher than what could be sustained for 30 to 60 minutes in conditioned individuals. To predict the HR response at VT2 using a 15- to 20-minute test, trainers can estimate that the corrected HR response would be equivalent to approximately 95% of the 15- to 20-minute HR average. For example, if an individual's average sustainable HR for a 20-minute bike test is 168 bpm, his or her HR at VT2 would be 160 bpm (168 bpm x 0.95).

This test is best performed using HR telemetry (HR strap and watch) for continuous monitoring. Individuals participating in this test need experience with the selected modality to effectively pace themselves at their maximal sustainable intensity for the duration of the bout. In addition, this test should only be performed by clients who are deemed low- to moderate-risk and who are successfully training in phase 3 (anaerobic endurance) of the ACE IFT Model.

Pre-test procedure:

- Briefly explain the purpose of the test, review the predetermined protocol, and allow the client the opportunity to address any questions or concerns.
- Take the client through a light warm-up (2- to 3-out-of-10 effort) for three to five minutes, maintaining a heart rate below 120 bpm.

Test protocol and administration:

- Begin the test by increasing the intensity to the predetermined level.
  - ✓ Allow the individual to make changes to the exercise intensity as needed during the first few minutes of the bout. Remember, he or she needs to be able to maintain the selected intensity for 20 minutes.
- During the last five minutes of exercise, record the heart rate at each minute interval.
- Use the average HR collected over the last five minutes to account for any **cardiovascular drift** associated with fatigue, thermoregulation, and changing blood volume.
- Multiply the average HR attained during the 15- to 20-minute high-intensity exercise bout by 0.95 to determine the VT2 estimate.

APPLY WHAT YOU KNOW

APPLYING THE RESULTS OF THE VT2 THRESHOLD TEST VT2 is commonly related to performance. For example, if two athletes with the same $\dot{V}O_2$max are competing, the athlete with the higher VT2 will likely outperform the other athlete. VT2 is improved by endurance training and high-intensity training (up to 105% of $\dot{V}O_2$max). At these intense training levels, the body can respond and adapt to the increased workloads, thereby "clearing" the blood lactate at a more efficient rate. In essence, training shifts the lactate curve to the right (Figure 2).

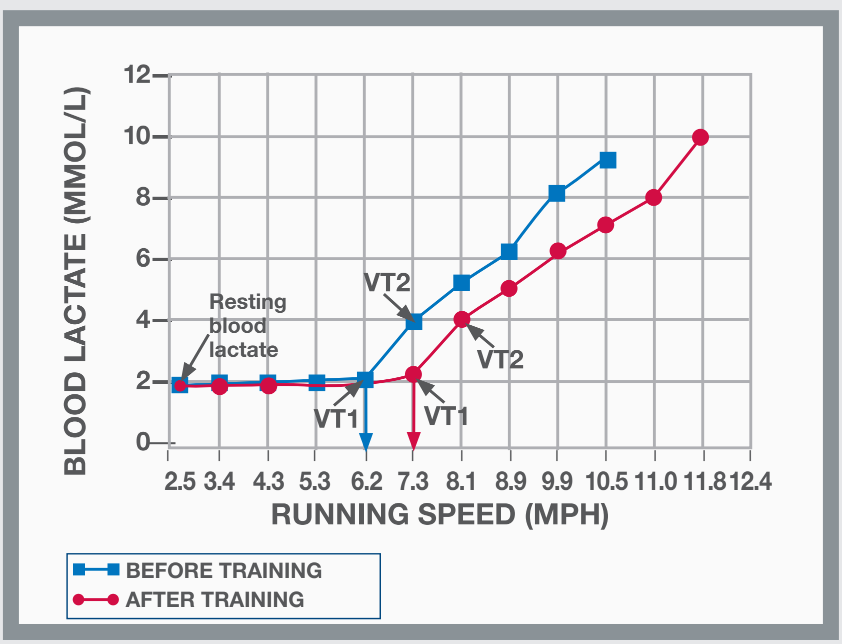

Figure 2
Effect of training on the lactate threshold

Note: VT1 = First ventilatory threshold; VT2 = Second ventilatory threshold