Beyond the Bruce Protocol

Advanced Exercise Testing for the Sports Cardiologist

Satyam Sarma, MD[a,b], Benjamin D. Levine, MD[a,b,*]

KEYWORDS

• Exercise • Bruce protocol • Sports cardiology • $\dot{V}O_2$

KEY POINTS

- The Bruce protocol is not an optimal test for many athletes; rather, exercise testing should aim to recreate the exact circumstances during which symptoms arise.
- Lactate measurement during exercise can provide valuable information regarding the athlete's trained status for his or her event and help to exclude deconditioning from the differential.
- Understanding the physiology involved in specific sports is important in assessing an athlete's performance.

Video content accompanies this article at http://www.cardiology.theclinics.com.

INTRODUCTION

For many clinicians, the Bruce protocol has become synonymous with exercise testing. Since its inception in 1950 to its evolution into the familiar 3-minute incremental stages by 1963, the protocol has quickly become the most common clinical treadmill exercise test.[1,2] A number of prognostic algorithms based on performance during the Bruce have been developed to inform clinicians on cardiac risk and prognosis, as well as functional capacity.[3–5] In this regard, the Bruce protocol has become the "go to" choice for the evaluation of exertional dyspnea.

When working with athletes, however, the Bruce protocol is rarely an optimal test because the goals for athletic testing are often different from the general public. In athletes, the purpose of testing is typically done to:

i. Evaluate baseline fitness and prescribe an exercise program or training zones;
ii. Evaluate continued progress after engaging in exercise training over a period of time;
iii. Diagnose cardiopulmonary conditions affecting exercise performance; and
iv. Provoke arrhythmias or evaluate hemodynamic response to exercise in an athlete with a known cardiovascular condition to determine whether it is safe to participate in competitive sports.

The key is to design a protocol that can safely and accurately answer these questions but is also tailored to the athlete's sport. Relying on a

The authors have nothing to disclose.

[a] Institute for Exercise and Environmental Medicine, Texas Health Presbyterian Hospital, 7232 Greenville Avenue, Dallas, TX 75231, USA; [b] Department of Internal Medicine, University of Texas Southwestern Medical Center, 5232 Harry Hines Boulevard, Dallas, TX 75390, USA

* Corresponding author. Institute for Exercise and Environmental Medicine, Texas Health Presbyterian Hospital, 7232 Greenville Avenue, Dallas, TX 75231.

E-mail address: BenjaminLevine@Texashealth.org

Cardiol Clin 34 (2016) 603–608
http://dx.doi.org/10.1016/j.ccl.2016.06.009
0733-8651/16/

"one size fits all" approach can result in an inappropriate test that gives false reassurance to both the athlete and clinician. This review recommends strategies in designing appropriate and relevant tests to answer athlete questions and provides examples of exercise testing in a variety of sporting disciplines.

GRADED EXERCISE TESTING

The graded exercise test should be familiar to most sports clinicians and consists of incremental increases in workload by varying speed, elevation or both. The standard Bruce protocol starts at 1.7 miles per hour at 10° inclination and increases elevation by 2° and speed by approximately 1 mph every 3 minutes. From completion of the first stage at 4 metabolic equivalents, each successive stage increases workload by approximately 3 metabolic equivalents. The quantum jumps in aerobic workload between stages are relatively large for patients with heart disease which makes it a suboptimal test even for patients let alone for athletes. Moreover, it relies much more on steep grades for driving up the work requirements, which for many athletes are uncomfortable and for competitive athletes often cannot elicit a true maximal effort.

A number of other graded exercise tests take a different approach from the Bruce. Rather than varying both speed and elevation, protocols such as the Naughton (2 mph) or Balke (3 mph) keep speed constant and shorten stage duration with elevation increasing by either 3.5% or 2.5% during each 2-minute stage. Although low speed, these protocols provide 1-metabloc equivalent quanta between stages, which make them especially valuable for patients. For an athlete trying to accurately determine heart rate training zones and continued progress from training, using an exercise protocol with higher resolution helps to define aerobic training parameters, although of course faster speeds will be required than are available in "standard" clinical protocols. In particular, when identifying ventilatory thresholds, the Bruce protocol will often underestimate this important aerobic measurement compared with graded exercise tests that have smaller increases in workload between stages.[6]

To account for the increased aerobic capacity of an athlete, a number of protocols have modified the treadmill speed. Protocols such as the Astrand (5 mph) or Astrand-Saltin (variable)[7] pick a relatively high speed and increase elevation by 2° in 2-minute stages. This still allows for 1-metabolic equivalent differences between stages and, because of high speed, shortens the test to 10 to 12 minutes. Picking the fixed treadmill speed is subjective but can usually be accurately estimated by having the athlete run at a pace that can be easily sustained for 30 minutes. It does not matter if this speed is 6 mph (10 min/mile pace) or 10 mph (6 min/mile/pace); picking a comfortable running speed and then only changing grade is essential for testing athletes.

At the end of the graded exercise test to exhaustion, the athlete should know his or her maximal aerobic power (can be estimated by treadmill protocol—ie, calculated from horizontal and vertical work—if breath-by-breath gas exchange is not available), maximal heart rate and as well as ventilatory threshold if breath-by-breath gas exercise system is available or by the Conconi method (ie, heart rate break point) if no gas exchange system is present.[8] Graded exercise testing can also be useful for detecting exercise or catecholaminergic arrhythmias and ischemia.

NONGRADED EXERCISE TESTING

Athletes rarely perform graded aerobic exercise to exhaustion. Rather, many events require sustaining relatively fixed workloads over short or long durations of sport, whereas other events require sudden bursts of high-intensity exercise followed by lull periods. Recreating the circumstances involved in performance limitations in a sporting event can be difficult and requires creative thinking. If an athlete develops fatigue in the last kilometer of a 5K race, the test needs to recreate the whole race. Similarly if a football player (American style) has shortness of breath between plays, the test needs to incorporate high-intensity intervals separated periods of rest.

Although recreating conditions for a cross-country running or paced endurance event is relatively straightforward, reproducing sports that have periodic bursts of aerobic power are more challenging. In designing a testing protocol, the first step is to discuss with the athlete what symptoms are to be reproduced and when during the event they occur (Fig. 1). Table 1 gives suggested frameworks for individual sports types, which can be used as a basis for designing the exercise protocol. Sports such as American style football or ice hockey require high degrees of exertion above lactate threshold, when lactate production exceeds clearance mechanisms and the skeletal muscles rely primarily on substrate-level phosphorylation. In these sports, a dedicated test of anaerobic capacity, such as a Wingate protocol,[9] or accumulated oxygen deficit (Medbo[10]) can be helpful in identifying limitations in substrate level capacity, although such tests are generally more