Field Test for Measuring Aerobic Capacity in Paralympic Goalball Athletes

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Athletes with visual impairments have a wide variety of sports available to them through the International Blind Sports Association. These sports include, but are not limited to, skiing, track and field, judo, swimming, tandem cycling, and goalball. Goalball was invented in 1946 by Austrian, Hanz Lorenzen and German, Sepp Reindle in an effort to assist in the rehabilitation of blinded soldiers. In 1976, goalball became part of the Paralympic Games.

Goalball is played on a standard volleyball court with three team-mates on each end of the court (Figure 1). The court has tactile markings for the player to determine his or her location on the court. Teams take turns throwing a ball that makes noise (bells inside) from one end of the court to the other in an attempt to get the ball in the goal. Goalball athletes have described the game as “reverse dodgeball.” By this they mean that instead of trying to avoid being hit by a ball, a goalball player purposefully dives in front of the ball to stop it from going into the goal. Most goalball players wear elbow and knee pads for protection. Some players also wear gloves and/or ice hockey pants.

Although players are classified by their visual acuity, they all wear blackened eye goggles as an equalizer. Competing in a visually-impaired sport requires many of the same physical attributes as those involved in able-bodied sports. Goalball can be compared to able-bodied sports such as volleyball and tennis with respect to explosive movements and interval activity. Thus, training for strength, power, and endurance are important components of success. Therefore, establishing standards for testing to assess preparation and performance for general and sport-specific fitness is essential. To date, there is a significant limitation in the research published regarding goalball. Studies in other sports for athletes with visual impairment are limited to classification and Paralympic swimming performance.

For able-bodied athletes, there are numerous methods of assessing cardiovascular fitness. The Astrand, Balke, and Bruce treadmill tests, the Cooper 12-minute run, the Queens College and Harvard step test, and the upper extremity ergometer test are just a few of the many tools that have been validated for the assessment of VO₂ maximum. Through the comparison with data collected using a metabolic cart, formulas have been developed for each of these tests to calculate maximal oxygen uptake. Likewise, the

**Key Points**

- Performance testing of Paralympic athletes is essential.
- Aerobic testing of visually impaired athletes presents challenges.
- The modified Beep Test is efficient and highly correlated to normative values.
Beep Test is a standardized task used by a wide variety of athletes to assess cardiovascular fitness. The Beep Test requires an athlete to run 20 meter intervals in response to an audible beep. The beeps are set at intervals that decrease as the test progresses. There are a total of 21 levels that begin at 8.5 km/hr and progress by 0.5 km/hr at each level. The reduced time requires athletes to increase their speed with each successive phase of the test. The Beep Test has normative values that correlate with maximal oxygen consumption levels (VO₂max). The test is not suitable for visually impaired athletes, however. The need for visual cues to run to predetermined targets at increasing speed is problematic. Visually impaired athletes need tactile cues to ascertain their bearings and to know when to change directions. Thus, the purpose of this study was to establish the content, concurrent, and predictive validity of a modified beep test to assess cardiovascular fitness in visually impaired athletes. This was determined by establishing a correlation between the standardized bicycle ergometer test (gold standard) and a modified beep test (concurrent validity). Furthermore, the calculation of a regression equation was used to establish predictive validity.

Procedures and Findings

Participants

Athletes recruited for this study were members of the United States Women’s Paralympic Goalball Team. These athletes regularly report to the Lakeshore Foundation for team training and are accustomed to being physically tested by the United States Olympic Sports Medicine staff. The testing protocol was performed during a regularly scheduled training session. All athletes were over the age of 18 years and had medical clearance to participate in strenuous athletic activity. Due to visual impairment, a researcher verbally read the entire consent form to the athletes. Following an opportunity to ask questions, each athlete signed a consent form approved by the University Institutional Review Board for the Protection of Human Subjects. Athletes provided demographic and medical history information.

The two measures of performance that were used to assess aerobic capacity were the bicycle ergometer test and the modified beep test. Random assignment was determined by the flip of a coin (heads = bicycle; tails = beep test). Each athlete performed both measures of performance with a minimum of 24 hours rest between the testing protocols. Athletes were thoroughly instructed in each of the testing protocols.

Bicycle Ergometer Test

For the bicycle ergometer test, a stationary bicycle (Monark) and a metabolic cart (ParvoMedics TrueOne® 2400) were used to conduct a graded exercise test for determination of VO₂max. Seat and bar height of the bicycle ergometer were set according to the participant’s specifications, and resting gas exchange data were obtained using the metabolic cart. Athletes placed a mask over their face and breathed naturally to obtain a baseline breathing level. With the mask still in place, the athletes began a four-minute warm-up period with a workload of 0.5 kp. Immediately after the warm-up, the work load was incremented by 0.25 kp each minute until the athletes reached their limit in tolerance. The linear scale of rating of perceived exertion (RPE) was used to evaluate the difficulty of a task; RPE was recorded at the end of each minute. Athletes were instructed to maintain a pedal cadence of 60 rpm during exercise and to exercise to volitional fatigue. Termination of the test occurred when the athlete was unable to maintain a pedaling cadence of at least 40 rpm, failure of heart rate to increase with increased exercise intensity, or the athlete requested to stop. Maximal oxygen consumption was assessed by the attainment of the following criteria: (a) a plateau in VO₂ (∆VO₂ < 50 mL/min at VO₂ peak and the closest neighboring data point) with increases in external work, (b) maximal respiratory exchange ratio (RER) > 1.1, and (c) maximal HR within 10 bpm of the age-predicted maximum (220 – age).

Modified Beep Test

The modified beep test was an activity cooperatively developed by the United States and Canadian National Team coaches and medical staff. Four experts collaborated in the development of the modifications to the beep test. The experts had a mean of 21 years of experience in the fields of goalball coaching, sports medicine, and exercise physiology. The clinical experts identified the items of importance to include in the modified beep test in order to establish content validity. The beep test involved performance of multiple rounds of shuttle-type running tasks specific to goalball with progressively shorter time intervals to complete each
Prior to completing the test, each athlete was physically taken through a slow-motion demonstration of the beep test protocol and had the opportunity to ask questions about the procedure. All athletes donned their game goggles for both testing procedures to eliminate visual feedback and simulate game conditions.

The entire modified beep test was implemented via a prerecorded CD to ensure standardization of the procedure. The athletes started at 12-second intervals and performed 10 repetitions of the following sequence of events:

- Standing at the “wing line” of a standardized goalball court (Figure 1), the athletes received an audible beep to signal the beginning of the test.
- The athletes dove to the floor in a typical defensive position.
- The athletes rose to their feet and ran forward to the “overthrow line” (Figure 1).
- The athletes ran backwards to the “goal line” (Figure 1).
- The athletes ran forward to the “wing line” and stopped.
- The athletes rested at the “wing line” until the next beep was heard.
- The sequence was repeated a total 10 times at 12 second intervals (level 1).
- The time interval of each subsequent round progressively decreased by one second and was repeated a total of 10 times each.
- This process continued until the athletes failed to return to the “wing line” within the specified time interval for two consecutive trials/stages within a round or when the athletes opted out of the testing protocol.
- No verbal encouragement was provided during either of the testing protocols. However, the athletes were verbally notified of any failed trial during the beep test protocol.

Seven of the nine female Paralympic athletes completed the tests. One athlete could not complete the ergometer test due to knee pain, and one athlete had an elevated blood pressure that was deemed unsafe for testing. Demographic data are displayed in Table 1. The data from the beep test and the bicycle ergometer test are displayed in Table 2. Final beep test levels ranged from 8.3 to 10.2. The average number of beep test rounds completed was 35.1 ± 7.8. The average VO₂max on the bicycle ergometer was 34.7 ± 7.5 ml/kg/min. In order to establish concurrent validity, a Pearson correlation between tests was calculated as r(5) = 0.77, p < 0.05 (SPSS 17.0). In order to establish predictive validity, a regression equation was calculated as:

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\text{Bicycle Ergometer } \text{VO}_2\text{max} = 3.466 + (0.91 \times \text{Number of Beep Test Rounds Completed})
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**Clinical Significance**

Due to the absence of data regarding the testing of visually impaired athletes, we sought to determine if the modified beep test was a valid measurement tool for the cardiovascular fitness of visually-impaired elite athletes. This study assessed content, concurrent, and predictive validity. Content validity is not a calculated value but rather is concerned with the inclusion of all of the content that was used to address cardiovascular performance.
Content validity is determined by expert opinion, in this case by the investigators, whose credentials have been established in this manuscript.

Concurrent validity was determined by establishing that a strong correlation (r = 0.77) existed between a known aerobic testing procedure (bicycle ergometer) and a game-specific testing protocol (modified beep test). This correlation indicates that the modified beep test is a useful test in determining cardiovascular fitness.

Finally, predictive validity was determined by the calculation of a regression equation. The regression equation for the modified beep test provides a y-intercept (3.466) and the slope (0.91) of a linear relationship between the two tests. Thus, one can multiple the number of rounds of the modified beep test completed by 0.91 and add 3.466 to obtain an athlete’s VO₂ max.

This study helps advance the knowledge of exercise testing in the persons with visual impairment. While the current study is limited by the small sample size, data collection of other international goalball teams is being pursued to increase sample size. The current results suggest the potential of the modified beep test as a valid measure of cardiovascular fitness in visually-impaired athletes. The benefits of the modified beep test are that it requires minimal equipment, permits testing of up to four players at a time, and takes less time than traditional cycle ergometry. The modified beep test is also a task specific protocol. Thus, the proposed protocol may serve as a more efficient and parsimonious method of aerobic testing of the visually impaired goalball athlete.

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References


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