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# Critical velocity as a measure of aerobic fitness in women's rugby sevens

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ABSTRACT

*Objectives:* To compare a field-based critical velocity running test to routine laboratory (treadmill $VO_2$ max test) and field-based (Yo-Yo intermittent recovery test, Yo-Yo IR1) aerobic fitness tests in women's rugby sevens (7's) players. To quantify the degree of association between field-based fitness test scores and GPS-derived analysis of performance data in competition.
*Design:* Single cohort, cross-sectional study involving 22 female Australian Rugby 7's National team players.
*Methods:* Players underwent fitness testing comparing the critical velocity test (100 m, 400 m, 1500 m runs) to the Yo-Yo IR1 and a treadmill $VO_2$ max test. GPS data was obtained during the National Championships using a subgroup of 12 players and compared with each player's fitness test scores.
*Results:* The critical velocity test was highly correlated with the Yo-Yo IR1 test ($r = 0.86$, 0.69–0.94; 90% confidence interval) and all variables of the $VO_2$ max test, however mean values were substantially different between tests (Yo-Yo IR1: $4.3 \pm 0.1\ m\ s^{-1}$, $vVO_2$ max: $3.7 \pm 0.3\ m\ s^{-1}$, critical velocity: $3.2 \pm 0.3\ m\ s^{-1}$). Average speed, obtained from GPS data, was largely correlated with both the Yo-Yo IR1 ($r = 0.62$, 0.10–0.87) and critical velocity ($r = 0.51$, −0.06–0.83) tests. Total game distance correlated moderately with the Yo-Yo IR1 ($r = 0.49$, −0.09–0.82) and critical velocity ($r = 0.36$, −0.25–0.76).
*Conclusions:* The critical velocity test is an appropriate aerobic fitness test, yields results similar to the Yo-Yo IR1, and correlates moderately with rugby 7's game data. However the Yo-Yo IR1 and critical velocity test scores cannot be used interchangeably.


## 1. Introduction

The introduction of women's rugby sevens (7's) to the 2016 Olympic Games has markedly increased the popularity and interest surrounding the sport. This scenario has lead to increased professionalisation within 7's, with many countries now supporting a full time program and dedicated staff.[1] A major component of a more professional approach is greater emphasis on the physical preparation of players. Coaches are seeking more information on the usefulness of physical fitness testing to assess a player's capabilities, quantify changes in fitness throughout a season, and for talent identification.

Simple fitness tests are commonly used to evaluate aerobic fitness in a variety of team sports such as rugby league, field hockey, Australian Football (AFL) and football (soccer).[2–4] Aerobic fitness measured by a laboratory-based maximal oxygen uptake ($VO_2$ max) test correlates highly ($r = 0.78$–0.87) with both the Yo-Yo intermittent recovery test (Yo-Yo IR1) and the multi-stage fitness test,[5] confirming that both are appropriate field tests for the measurement of aerobic fitness. The Yo-Yo IR1, tailored specifically for intermittent-based activities, is ideal for team sports more than the continuous motion of the multi-stage fitness test. The Yo-Yo IR1 test correlates highly with distance covered ($r = 0.53$) and high intensity running ($r = 0.71$) during soccer matches,[6] and discriminates between selected and non-selected AFL players[4] and elite and semi-elite rugby league players.[7] Other physical performance tests such as time trials[8] and critical velocity[9] are also useful for assessing aerobic fitness. While these tests differ in locomotion, with potential variation in energetics used, there are still questions on the relationship and interchangeability of different aerobic fitness tests. Understanding the variations between available tests is important for coaches and testing staff. The ability of these tests to relate to the demands of competition also needs to be considered when choosing an appropriate test to assess aerobic fitness in rugby 7's.

Critical velocity testing is not typically performed by intermittent-based team sports, however, it appears to have the potential as a worthwhile and easily accessible aerobic fitness

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test. Frequently performed under laboratory conditions using a treadmill or cycle ergometer, critical velocity testing is capable of determining individual athletes' threshold speed which can theoretically be maintained for an extended period without fatigue.[10] Briefly, an athlete completes a series of maximal efforts at progressively increasing speeds or power outputs in the same testing session. Graphed as distance (or power) over time, the individual's critical velocity is determined as the slope of the regression line. This test has been modified for the use by some professional teams within rugby league and rugby union,[9,11] and allows multiple players to test in small groups simultaneously, while using minimal equipment, on any outdoor training ground. Critical velocity can also be used for exercise prescription, as working above this threshold causes marked increases in blood lactate and decreases in muscle pH.[12,13] However, a direct comparison between the critical velocity test and more common tests such as the Yo-Yo IR1 and $VO_2$ max tests has yet to be undertaken.

While the use of GPS monitoring in rugby 7's is in its infancy, some studies have quantified match demands in both the men's[14] and women's[15] game using this technology. Female players have been found to cover around 1500 m during domestic games with 9% of the time spent at high intensity (>18 km $h^{-1}$).[15] The fitness levels required for players to be competitive at domestic and international tournaments are still unclear. To obtain relevant aerobic fitness test results for 7's players it is important to understand which endurance running test is most appropriate, and correlates the highest, to on-field running performance.

The aim of this study was to compare a field-based critical velocity running test to routine laboratory and field-based tests of aerobic fitness in women's rugby 7's players. Results were analysed as a common metric of running velocity (m $s^{-1}$) to facilitate a direct comparison of tests. A secondary aim of this study was to quantify the degree of association of these aerobic field tests with (running) performance data in competitive matches.

## 2. Methods

A single cohort, cross-sectional study was conducted on 22 females in the National 7's squad (age 25 ± 5 y, mass 69 ± 7 kg, height 1.68 ± 0.06 m, sum of seven skinfolds 85 ± 15 mm, mean ± SD). Players underwent a series of field and laboratory-based aerobic fitness tests over several weeks to establish relationships between tests and their relevance to rugby 7's. Written informed consent was obtained from all players after approval from the University of Canberra Committee for Ethics in Human Research, and the Australian Institute of Sport Ethics Committee.

As a team, players visited the physiology laboratory and outdoor field on two occasions during their competitive season to undertake various fitness tests. On the first visit players completed a Yo-Yo IR1 test and critical velocity running test on consecutive days. The second visit had players perform a treadmill $VO_2$ max test and the critical velocity running test the following day. GPS match data was obtained midway through the study at the National Sevens Championships using a subgroup of 12 players.

Before each testing session players completed a pre-exercise screening questionnaire to ensure illness/injury would not affect their ability to perform maximal exertion tests. A standardised 15 min warm-up, comprising running and stretching, was performed as directed by the team strength and conditioning coach. During all testing sessions players were verbally encouraged to perform maximally. Heart rate was recorded throughout all testing sessions (Memory Belt Heart Rate Monitor, Suunto Oy, Vantaa, Finland) to determine peak heart rate.

All participants were familiar with the Yo-Yo IR1 test[6] and had performed it at least once before the commencement of this study. The test was performed on an indoor running track with environmental conditions of 24 °C and 79% humidity. This test is considered reliable for team-sport players, with a coefficient of variation (CV) of 4.9%.[6] A 5 μL capillary blood sample was drawn from an earlobe three min after cessation and blood lactate concentration determined using a hand-held analyser (Lactate Pro, Arkray, Japan)[16].

The critical velocity running protocol examined in this study was based on versions used at other professional rugby league and rugby union clubs.[9,11] A 100 m straight line track was marked out on a well-maintained outdoor grass football field (ambient temperature 14 ± 9 °C, humidity 86 ± 1%) and players performed maximal effort out and back runs over 100, 400 and 1500 m. The time to complete each distance was recorded in seconds using a manual stopwatch (S056-4000, Seiko, Japan). Each individual subject's critical velocity (m $s^{-1}$) was computed by the slope of the regression line when plotting distance (m) against time (s). Active recovery involving walking and slow jogging for four min (following the 100 m effort) and 12 min (after the 400 m effort) was performed. A 5 μL capillary blood sample from an earlobe was taken three min after completion of the 1500 m run to determine blood lactate concentration.

The $VO_2$ max test was performed on a custom-built (Australian Institute of Sport) motorised treadmill. The protocol comprised a continuous submaximal stage followed by incremental running to volitional exhaustion.[17] Players completed 3–6× 4 min submaximal stages starting at 9 km $h^{-1}$ (0% gradient). Each stage was separated by 2 min recovery with the velocity of the following stage increasing by 1 km $h^{-1}$. A 5 μL capillary blood sample was taken from the fingertip immediately after each stage and analysed for blood lactate concentration. Players completed a minimum of three submaximal stages or continued until they reached the lactate threshold of 4 mM. A 5 min recovery period was given before the commencement of the incremental stage. The incremental stage began at 9 km $h^{-1}$ (0% gradient) and increased by 0.5 km $h^{-1}$ every 30 s until the velocity during the last submaximal stage was reached. At this point velocity remained constant while gradient increased by 0.5% every 30 s until volitional exhaustion. Heart rate and expired air ventilation were recorded continuously during the test and blood lactate was measured 3 min following completion. The criteria for $VO_2$ max comprised a plateau in $O_2$ uptake (<0.10 L difference in $O_2$ between consecutive measurements) or a respiratory exchange ratio (RER) ≥ 1.10. The treadmill was calibrated at the start of each day of testing and the gas analysers before each test. The CV of the protocol in this laboratory is 2.6%. The various submaximal and maximal measures assessed during this test included speed at 4 mM, $VO_2$ max (mL $kg^{-1}$ $min^{-1}$ and L $min^{-1}$) and velocity at $VO_2$ max ($vVO_2$ max).

Performance data during the National 7's Championships were assessed using GPS devices (SPI Pro X, GPSports Systems, Australia) recording at 5 Hz. Similar 5 Hz devices have a reliability of 1.8–2.3% CV when measuring distance travelled and 1.6–2.1% CV when measuring speed.[18] The GPS unit was positioned between the scapulae of the players using an elastic harness, worn underneath the playing jersey. The half time interval was excluded from analysis, as was the final match, due to the longer game duration (20 min vs. 14 min). Players who were involved in substitutions during games were excluded given prior research showing that (fresh) substitutes run faster in game play.[19] A total of 24 game files were included for analysis. Variables were reported as the mean value achieved during a full game for each individual athlete.

Each test score (level: shuttle) from the Yo-Yo IR1 and individual's $vVO_2$ max were converted to the same metric as the critical velocity running test (m $s^{-1}$). From the Yo-Yo IR1 test, this value was the theoretical speed derived from the actual running speed at the final level attained, adjusted upwards based on how many shuttles within that level the player completed (vYo-Yo IR1).