

# Field Tests of Cardiorespiratory Fitness for School Children 測試學童心肺耐力適能的方法

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## Abstract

Cardiorespiratory (CR) fitness is an important component of the health-related physical fitness. CR fitness is related to oxygen delivery to muscles involving heart, lungs and circulatory system that enabling large muscles to work for a longer period of time. The most accurate reflection of CR fitness is maximal oxygen uptake ( $VO_2$  max) at work. However, the test involves expensive laboratory equipment such as treadmill, cycle ergometer and gas analyzer. Field tests such as distance running tests and step tests are more appropriate to be used during physical education lesson. This article aims to introduce a few field tests for CR fitness to be used in schools.

## 摘要

心肺功能是健康相關體適能要素裡其中一主要項目，心肺功能是指心臟、肺部和循環系統有效地供給氧份，使整個身體能作出較長時間的大組肌肉運動。最準確的心肺功能測驗方法是分析運動中的最大攝氧量( $VO_2$  max)，但這種方法需使用較昂貴的器材如跑步機、單車及氣體分析器等，而且只可在實驗室內進行。相反，一些可在一般場地進行的測試如跑步測試、台階測試等，均適合在學校的體育課中進行。本文將介紹幾種適合一般場地舉行的心肺功能測試並闡釋其運作理念。

## Introduction

Cardiorespiratory (CR) fitness is the ability to perform large muscle, whole body, dynamic, moderate-to-high intensity exercise for relatively long periods of time. It involves the functioning of the circulatory and respiratory systems to supply oxygen for the muscles to do physical work. In order to achieve the best CR benefits, ACSM (2000) gave the following general guidelines of aerobic exercise prescription for healthy individuals:

- Intensity - 55/65% to 90% of maximum heart rate (predicted  $HR_{max} = 220 - \text{age}$ );
- Duration - exercising at 70-85%  $HR_{max}$  for 20-30 minutes (excluding warm-up or cool down time); and
- Frequency - 3 to 5 days per week.

CR fitness is considered health-related. The importance of CR fitness has been explicitly explained by ACSM (2000) as (a) Low levels of CR fitness have been associated with a markedly increased risk of premature death from all causes and specifically from cardiovascular disease, (b) increases

in CR fitness are associated with a reduction in death from all causes, and (c) high levels of CR fitness are associated with higher levels of habitual physical activity, which are, in turn, associated with many health benefits. (p. 68)

The best single measure of CR fitness is maximal oxygen uptake ( $VO_2$  max), however, accurate direct  $VO_2$  max tests require expensive laboratory equipment such as treadmill or cycle ergometer and gas analyzer. Field tests like running tests and bench stepping tests have been designed to measure CR fitness, and most are suitable for group testing during physical education lesson. The intent of this paper is to introduce several field tests of CR fitness to be used during physical education lessons.

## Distance Run Tests

The validity of running tests for CR fitness depends by the amount of distance covered or the duration of running time. Past studies conducted in the 70s based on factor analysis have found running tests less than 402 m (or 440 yards) in distance

measure speed. Running test of 1600 m (1 mile) or 9 minutes or longer measure endurance, while tests of intermediate distance and duration (549 m to 731 m or 600 to 800 yards and 3-6 minutes) measure both speed and endurance (Baumgartner & Jackson, 1995). The most common distance run tests for CR fitness measure are 1-mile (1600 m) or 9-minute runs and 1.5 mile (2400 m) or 12-minute runs. The test courses for these run tests can be varied by using standard athletic track, basketball court or indoor-court area (see Table 1 for different run test standards). These tests have been found to be valid and are related to  $VO_2$  max. However, physical education teachers should be aware of individual factors such as body fatness, running efficiency, maturity and motivation can affect distance run time. Other factors like environmental temperature, humidity and running surface also affect testing results.

### 6/9-minutes Run/Walk Test

The Secondary and Primary School Physical Fitness Award Scheme jointly presented by Education Department and Hong Kong ChildHealth Foundation in Year 1999 adopts the 9-minute run for students over 8 years old. Students under 9 years old take the 6-minute run test. The test requires a student running or walking around a basketball court of 15 by 25 metre at the specified time (Hong Kong ChildHealth Foundation, 1999). Cones are placed in 10-m distance. The total distance covered is counted up to the last nearest cone reached by the student. Since most schools have a standard basketball court, this test is deemed to be more suitable to the local school environment than other distance run tests.

### 20 Metre Multistage Shuttle Run Test

Traditional shuttle run tests normally measure agility component of the motor-related physical fitness. However, the 20-m multistage shuttle run test has been designed to measure CR fitness, which was first developed by Leger and Lambert in 1982 and was modified for children (Leger, Mercier, Gadoury & Lambert, 1988). It is suitable to be used in schools as it requires minimal equipment and it can be mass testing. Validity evidences for this test have been conducted on school children in USA, UK, Quebec and Hong Kong. Barnett, Chan and Bruce (1993) measured 55 Hong Kong secondary school students and found the test to be a good predictor of peak  $VO_2$ . This test was an item (option for replacing 1.6 km run/walk) in the Australian Fitness Education Award for students aged 9-18 (ACHPER, 1996) and was offered (named as The PACER) as an option for 1-mile run/walk in the Prudential FITNESSGRAM (1992) for grades K-12 students in USA.

The objective for 20-m multistage shuttle run test is to run back and forth on a 20m course and must touch the

20m line or within the 19m zone when a sound signal is emitted from a prerecorded tape. The frequency of the sound signals increases by 0.5 km/hr each minute to the next level with a starting speed of 8.5 km/hr for the first level. Therefore each level consists of different number of shuttles, as speed increases for higher number level, the number of shuttles increases. The test stops when the student cannot reach the 19m zone consecutively two times when the sound signal is emitted. A final score of 10.8 means the student completes 8 shuttles at level 10. The test will finish within 20 minutes since level 20 indicates extremely high predicted  $VO_2$  max values exceeding 80 ml/kg/min which means excellent CR fitness.

This 20m shuttle run test has several practical advantages over the traditional distance runs. First, it can be tested in a relatively small space either indoors or outdoors, therefore it is a practical test for schools in Hong Kong without athletic track area. The problem of pacing is eliminated because running pace is controlled. The test is incremental and hence submaximal for much of its duration. As the test requires maximal effort towards the latter stage of testing (last 1-2 minutes), students may not be motivated to run throughout the whole time and they should be allowed to quit at any time. To overcome the lack of motivation factor, physical education teachers can set certain criterion standard (level and shuttle) for students to reach for CR fitness (see Table 1 for Australian Education Fitness Award Standards). Students can be encouraged to go for higher level if higher grades are awarded. The test can be conducted on athletes to show their improvement in CR fitness after sport training.

### Bench Stepping Tests

Bench stepping is a very inexpensive form of exercise requiring little equipment. It can be used for both submaximal and maximal testing. The earliest bench stepping test, Harvard Step Test (Brouha, 1943) was originally developed for college males. The test requires a subject stepping up and down on a bench 20 inches high by following a set cadence (30 times "up" "down"/minute) for five minutes. Pulse is counted 1 minute after exercise for 30 seconds (by using the Short Form) and then the Physical Efficiency Index (PEI) is calculated by the scoring formula as:

$$PEI = \frac{[\text{duration of exercise in seconds} \times 100]}{[5.5 \times \text{pulse count for 1 to 1 1/2 minutes after exercise}]}$$

The Harvard Step Test has since been modified either by changing the cadence or bench height so that it can be tested on school children. The Harvard Step Test for Elementary School Males and Females uses bench height of 14 inches. The cadence and scoring formula are the same as the original Harvard Step Test (Brouha & Ball, 1952).

The major advantage of using step tests to assess CR fitness is that they can be mass testing without expensive equipment. However, the validity of step tests depends on accurate measurement of pulse rate. Students have to teach how to measure own pulse rates or partner's pulse.

**Conclusion**

The most concerns for valid physical fitness tests used in physical education lessons are ease of preparation, inexpensive equipment, mass testing, safe and appropriate for school children. The field tests mentioned in this article are suitable for CR fitness measure. Physical education teachers can set their own norms for different sex and different age level after one-year data. Teachers can also use criterion-referenced standards for CR fitness provided by other countries' major test battery (found in test and measurement textbooks). The CR fitness standards are set by experts based on elaborate exercise physiology research and are generally treated as acceptable standards.

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**Table 1. Criterion-referenced Standards for Different Run Tests**

Test Items	Age								
	10	11	12	13	14	15	16	17	18
	BOYS								
1 Mile Run (min)*	11:30	11:00	10:30	10:00	9:30	9:00	8:30	8:30	8:30
9 minutes Run (m)**	1480	1582	1700	1811	1811	1811	1811	1811	1811
9 minutes Run (m)***	1500	1500	1580	1660	1717	1780	1790	1800	1840
20-m Multistage Shuttle Run****	3.6	5.1	5.4	5.9	6.6	7.8	8.5	8.5	8.5

  

Test Items	GIRLS								
	10	11	12	13	14	15	16	17	18
1 Mile Run (min)*	12:30	12:00	12:00	11:30	11:00	10:30	10:00	10:00	10:00
9 minutes Run (m)**	1480	1509	1609	1609	1609	1609	1609	1609	1609
9 minutes Run (m)***	1340	1380	1360	1380	1370	1370	1410	1400	1428
20-m Multistage Shuttle Run****	3.4	3.5	4.1	4.3	5.1	5.3	5.5	5.5	5.5

Note: \* Prudential FITNESSGRAM (1992)  
 \*\* South Carolina Physical Fitness Test (1983) (Miller,1998, p. 204)  
 \*\*\* Hong Kong ChildHealth Foundation (1999); standards are based on 75<sup>th</sup> Percentiles  
 \*\*\*\* Australian Fitness Education Award (ACHPER, 1996)  
 Score: e.g. 3.6 represents completion of level 3 and 6 shuttles of 20-m