**Biology of Sport, Vol. 20 N°1, 2003**

# EXERCISE CHARACTERISTICS OF PHYSICAL EDUCATION TRAINEE TEACHERS IN SINGAPORE AND THE VALIDITY OF FIELD AEROBIC AND ANAEROBIC PERFORMANCE TESTS

**M.Chia**

*Physical Education and Sports Science, National Institute of Education, Nanyang Technological University, Singapore*

**Abstract.** The study provides exercise data on the aerobic (shuttle-run test) and anaerobic (stair-run test) field performances of physical education trainee teachers in Singapore and validity data on the field performance tests. Fifty subjects (22 female and 28 male) participated in the study. Male subjects were significantly ($P<0.05$) older (26.2±3.1 y versus 23.1±1.4 y), taller (1.71±0.07 m versus 1.61±0.06 m), heavier (66.2±11.3 kg versus 51.4±5.1 kg) and had lower sum of four-site skinfolds (29±11 mm versus 38±12 mm) than the female subjects. They also had greater predicted oxygen uptake peak (48±5 versus 39±4 ml/kg body mass/min, $P<0.05$; ES=2.0) and peak power (16.8±2.6 versus 12.9±1.3 W/kg body mass, $P<0.05$; ES=2.0) than the female subjects. Differences in exercise performances were largely attributed to the differences in body composition between the sexes. The shuttle-run test and the stair-run test were highly correlated with the treadmill laboratory test ($r=0.89$, $P<0.05$) and the Wingate Anaerobic Test ($r=0.77$, $P<0.05$), respectively. Aerobic field performance was not correlated with anaerobic field performance ($r=-0.1$ for male, $r=0.3$ for female, both $P>0.05$). This study ameliorates the paucity of exercise data on PE trainee teachers in Singapore, and confirms the validity of field performance tests in assessing the exercise performance in this cohort of subjects.

***(Biol.Sport 20:43-52, 2003)***

*Key words:* Peak $VO_2$ - Wingate Anaerobic Test - Shuttle-run - Stair-running

---

Reprint request to: Dr. Michael Chia, BASES-accredited Exercise Physiologist, ACSM-certified Health/Fitness Director, Physical Education and Sports Science National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616, Singapore; Tel.: 65-67903701; Fax: 65-6896 9260 e-mail: yhmchia@nie.edu.sg

## Introduction

Established data on the aerobic and anaerobic performances of physical education (PE) trainee teachers are apparently non-existent in Singapore, albeit, related data are abundant elsewhere. For instance, Inbar, Bar-Or and Skinner [7] have published Israeli norms for Wingate Anaerobic Test performance of physical education teachers, while Ramsbottom, Brewer and Williams [13] have published peak oxygen uptake values of physical education undergraduates. Aerobic and anaerobic fitness are key pre-requisites for optimal performance in many sports and physical activities. The accepted 'gold standards' for assessing aerobic and anaerobic fitness of subjects are laboratory tests since they are more valid and reliable than field performance tests. In the laboratory, maximal oxygen uptake or more appropriately, oxygen uptake peak ($VO_2$ peak) is normally assessed by directly measuring oxygen uptake during an incremental treadmill run to volitional exhaustion. $VO_2$ peak represents the highest amount of oxygen that the body can use and it is the most accepted criterion for assessing aerobic fitness [1]. There are a variety of laboratory tests that are used to assess anaerobic fitness. The most widely used test for assessing anaerobic performance is the Wingate Anaerobic Test (WAnT) [7]. Unlike aerobic performance where $VO_2$ peak is often taken to be synonymous with aerobic fitness, there is no universally accepted marker for assessing anaerobic fitness [4]. However, peak power (P) (defined as the highest power attained over 1s) has often been used to describe the anaerobic performance of young people [5] and also in adult populations [7].

The direct determination of oxygen uptake during incremental progressive exercise requires sophisticated and expensive equipment (usually a motorised treadmill connected to a computerised on-line gas analysis system), laboratory time and trained personnel. The WAnT has been the laboratory test of choice for the assessment of anaerobic performance [4]. Although the anaerobic test is less time consuming than the laboratory test used to assess aerobic performance, both these laboratory tests are not practical for testing large groups of subjects. PE practitioners who do not have access to expensive laboratory time are therefore reliant on surrogate field performance tests to estimate aerobic ($VO_2$ peak) and anaerobic (PP) fitness.

Field performance tests for the prediction of $VO_2$ peak require subjects to cover a set distance (e.g. 1000 m or 2000 m) in the fastest time or cover the maximum distance over a set time (e.g. 12 min or 15 min) [10]. Such aerobic fitness tests require that subjects are well motivated to do their best, that they have some knowledge of pace judgement as the tests are maximal from the onset, and that they are familiar with the test requirements. An aerobic field performance test that has gained some popularity is the 20 m progressive shuttle-run test to volitional exhaustion [13]. The test has been described as having high validity (r=0.92) when compared with laboratory-determined $VO_2$ peak for a group of British PE students [13]. However, its validity in assessing PE trainee teachers in Singapore has apparently not been appropriately established.

Field performance tests for assessing anaerobic performance include sprinting ability such as 50 m sprint times or distance covered over 40 s; jumping ability such as vertical jumps or jumps for distance; and performance tasks such as stair-running. These tests are of a short-duration and require the subjects to give an all-out or supra-maximal effort from the onset of the test. The Margaria stair-run test [10] was the pre-eminent test of anaerobic power prior to the introduction of the WAnT. PP scores are reported to be highly correlated with PP derived from the WAnT, where r values of 0.77 and 0.84 have been reported in untrained and trained subjects, respectively [2].

In Singapore, the training of PE trainee teachers involves an active participation in practical modules each of 18 hours' duration, for a pheltora of physical activities and sports such as gymnastics, dance, outdoor education, weight training, team games (e.g. soccer, hockey, netball, basketball, volleyball, badminton, tennis, squash, etc) and swimming, over a two-year period. The training requirements are over and above the compulsory academic modules (e.g. exercise physiology, biomechanics, skill acquisition, etc.) that are each of 26 hours' duration. As aerobic and anaerobic performance proficiency are pre-requisites to optimal performance in team sports that form the core practical modules for the formal PE qualification in Singapore, it is important to have a ‘snapshot’ of the aerobic and anaerobic fitness of the PE trainee teachers. Therefore the purpose of the study was to establish the validity of aerobic and anaerobic field performance tests and to elucidate the surrogate field performance tests results of PE trainee teachers.

## Materials and Methods

*Subjects*: Fifty first-year subjects (female N=22; male N=28) who were into their first semester as trainee teachers in PE gave written informed consent to take part in the study. All subjects were involved in 12-15 h of practical physical activity per week (e.g. volleyball, hockey, gymnastics and swimming) as part of their scheduled programme for the first semester of the academic year. None of the subjects were involved in any specialised aerobic or anaerobic training of their own. As a guide, the number of subjects recruited for the study was based on a sample size computation that took into account, (i) the aerobic and anaerobic (peak $VO_2$ and PP) performance data of six subjects and (ii) an effect size of 0.5 and power of 80%.

*Physical measurements*: Sums of skinfolds were obtained using a Harpenden caliper (Quinton Instrument, Seattle) at four sites: subscapular, biceps, triceps and suprailiac, in accordance to the technique described by Durnin and Womersley [6]. Calendar age, stature and body mass were also measured using standard procedures.

*Field performance tests*: All subjects were familarised to the performance tests as they have been exposed to similar test conditions in a previously taught module. Each subject completed a 20 m shuttle-run test [13] and a stair-running test [11], on two separate occasions that were conducted within a week of each other. The order of the tests was randomised for each subject. Over the testing week, the trainees continued with normal physical activities but were instructed to refrain from any strenuous physical activity 24 hours prior to testing.

*Standardised warm-up protocol*: Prior to each of the tests, subjects were taken through a standardised warm-up procedure that consisted of three minutes of a slow jog, followed by another two minutes of stretching for the hamstrings, quadriceps and groin.

*Twenty-metre shuttle-run test*: The 20 m progressive shuttle-run test used in the present study has been described in detail elsewhere [13,15]. Essentially, the test consisted of shuttle running between two markers placed exactly 20 m apart at increasing fast speeds. The test was conducted on a wooden gymnasium surface. The running speed increased 0.14 m/s each minute and this change in speed was described as a change in level. The running pace was dictated by an audio player (National: model WA-190 N) with pre-recorded instructions, in accordance to the procedures outlined by Ramsbottom *et al.* [13]. Subjects completed as many levels as they could till volitional exhaustion prevented them from keeping up with the increased running pace. Recorders were on hand to record the number of levels and stages successfully completed. Predicted $VO_2$ peak in body mass-accounted terms was then derived from a table of Ramsbottom *et al.* [13]-generated norms for PE students.

*Stair-running test*: The test involved running up a flight of stairs, taking two 0.175 m steps at a time, at top speed from an initial two metre run-up. Pressure mats, placed on the $8^{th}$ and $12^{th}$ stairs were linked to an electronic timer (sensitivity:0.01 s) that allowed the time taken for the sprint to be measured. Subjects performed this test twice with a short rest between the two attempts. The faster of the two attempts was recorded. With the vertical height (m) between the pressure mats, and the subject's body mass (kg) known, peak power (W) was computed according to the following equation:

PP = [Body mass x 9.81 x vertical height] / time, where 9.81 is the acceleration due to gravity in $m/s^2$. PP was then expressed in body mass-accounted terms.

*Validity tests*: Twenty randomly selected subjects (10 male, 10 female), from the same subject population also completed two additional laboratory tests-namely, an incremental run test to volitional exhaustion on a motorised treadmill to determine $VO_2$ peak using a standardised Bruce protocol and also a 30 s WAnT to determine PP derived over 1s. The laboratory tests were conducted on two separate occasions that were organised one week prior to the main test series.

*Statistical analyses*: The Statistical Package for Social Sciences (SPSS 10.0 for Windows) was used for statistical analyses. Descriptives (means and standard deviations) of the subjects and their performances in the field exercise tests were computed. Independent t-tests were used to determine if significant differences existed between the sexes in terms of their physical characteristics and exercise performances. Where appropriate, effect sizes were computed to determine the meaningfulness of the detected differences in performance. Pearson product moment (inter-class) correlation coefficient was used to confirm the validity of the field tests with the laboratory tests and also to describe the strength of relationships between the subjects' aerobic and anaerobic field performances. Repeated measures analysis of variance was used to analyse the laboratory and field based data in a sub-cohort of the subjects. Where appropriate effect size (ES) was computed to estimate the meaningfulness of the differences between the groups. The level of statistical significance was set at P <0.05.

## Results

**Table** 1
Physical characteristics of the Singapore PE trainee teachers segregated by sex

| Variables | Male (N=28) | Female (N=22) |
|---|---|---|
| Age (y) | 26.1±3.1 | 23.1±1.4∗ |
| Stature (m) | 1.71±0.07 | 1.61±0.06∗ |
| Body mass (kg) | 66.2±11.3 | 51.4±5.1∗ |
| Sum of 4-site skinfolds (mm) | 29±11 | 38±12∗ |

∗differences between the means are significant at P<0.05

*Subject characteristics*: The physical characteristics of the subjects, segregated by sex are summarised in Table1. In essence, male PE trainee teachers were significantly older, taller, heavier and had lower sum of 4-site skinfolds than the female PE trainee teachers.

*Validity of the field performances*: Inter-class bivarate correlations between the laboratory tests and the field performance tests were significantly high (i.e. directly determined $VO_2$ peak in comparison to shuttle-run-predicted $VO_2$ peak: r=0.89, P<0.05; WAnT-derived PP in comparison to stair-run-derived PP: r=0.77, P<0.05).

*Differences between laboratory-determined performances and field performances*: For the sample of 10 male and 10 female subjects (a sub-sample of the main subject cohort), laboratory-determined $VO_2$ peak was significantly higher than that predicted from the 20 m-shuttle-run (male: 51±4 versus 48±5 ml/kg BM/min, ES=0.86; female: 43±3 versus 39±4 ml/kg BM/min, ES= 1.14, both P<0.05).

Stair-run-determined PP was significantly higher than 1s PP derived form the WAnT (male: 16.8±2.6 versus 14.7±2.3W, ES=0.86; female: 12.9±1.3 versus 10.5±1.9 W, ES=1.5, both P<0.05).

*Predicted $VO_2$ peak and PP of the subjects*: The field performances of the 50 subjects are summarised in Table 2. Males had 23% higher $VO_2$ peak, and 30% higher PP than the female subjects.

**Table 2**
Field performances of Singapore PE trainee teachers segregated by sex

| Variables | Male (N=28) | Female (N=22) | Effect size (ES) |
|---|---|---|---|
| Shuttle-run-derived predicted $VO_2$ peak (ml/kg BM/min) | 48±5 | 39±4* | 2.0 |
| Stair-run derived PP (W/kg BM) | 16.8±2.6 | 12.9±1.3* | 2.0 |

*differences between the means are significant at P<0.05

*Bivariate correlations between predicted $VO_2$ peak and PP:* Pearson product moment correlation coefficient between predicted $VO_2$ peak and PP, in body mass-related terms, failed to attain statistical significance (r=-0.1 for male and r=0.3 for female, both P>0.05).

## Discussion

The study provided aerobic and anaerobic performance data of a cohort of PE trainee teachers in Singapore, ameliorating the paucity of performance data on this population. Mirroring the data from many other countries, the exercise performances of the male subjects were significantly greater than that of the female subjects, in tasks that can be described as predominantly aerobic (shuttle-run test) and predominantly anaerobic (stair-running test), even when the respective results were ratio-matched for differences in body mass. Results from the study showed that predicted $VO_2$ peak values were 23%, and stair-run-derived PP values were 30% higher in male subjects than in female subjects (Table 2). The sex differences in fitness performances are buttressed by the high effect sizes (ES=2.0) obtained. This demonstrated that the male PE trainees out performed the female PE trainees significantly. Some of these differences may perhaps be explained by the differences in body composition between the male and female subjects, especially since, the female subjects had 31% greater sum of 4-site skinfold values than the male subjects (Table 1). Other data suggest that the sex differences in aerobic capability may be attributed to, to a smaller exercise stroke volume in girls and women, lower relative haemoglobin concentration [1]. In the case of sex differences in anaerobic performance, data published elsewhere suggest that male-female differences in anaerobic performance could somewhat but not completely attributed to differences in muscle mass, levels of circulating testosterone as well as inherent cultural expectations of men and women [1].

However the results are insightful in that steps must be taken to ameliorate the gender divide in fitness performances as both males and females often compete together as in games modules during their training. Alternatively, a case may be put forward to have some activities to be segregated by sex so that the sexes compete on more equal terms.

The predicted $VO_2$ peak of the subjects in the present study is in general agreement to an earlier study on PE trainee teachers in Singapore that also used the shuttle-run test. Sproule, McNeil, Kunalan and Wright [15], reported that Singapore PE trainee teachers had predicted $VO_2$ peak values of 49±7 ml/kg BM/min, albeit they reported on pooled male and female data, and the subject sample size in their study was relatively small (i.e. 16 male and 4 female). The present predicted values for both male and female subjects were however lower than those reported by Ramsbottom *et al.* [13] for British PE students. Subject cohort differences (e.g. different race), differences in entry-level fitness levels, differences in patterns of physical activities and differences in climatic conditions between the two countries may explain some of the differences observed. For instance, exercise in hot and humid conditions in Singapore (mean March temperature 31$^0$C; mean relative humidity 65%) may impair oxygen transport capacity to the exercising muscles and may affect overall performance [12].

There are apparently no published anaerobic performance data of PE trainee teachers in Singapore. However, peak power (PP), derived from the stair-run test in the present study compares favourably with other studies that employed a similar test protocol (i.e. 16.8 versus 16.7 W/kg BM), for male PE students [14] and for female PE students (i.e. 12.9 versus 12.3 W/kg BM) [14]. A notable observation was that the stair-run-derived PP in the present study was significantly greater than the 1 s PP derived from the WAnT in the sub-sample of subjects tested. This is not surprising since, in the WAnT, the body mass is largely supported, and PP is derived predominantly from the efforts of the lower limbs, whereas in the stair-running test, the entire body mass is involved in generating the power produced [4].

The results of the present study established and confirmed the validity of the use of field performance tests for estimating aerobic and anaerobic proficiency for PE trainee teachers in Singapore. The inter-class correlation coefficient of 0.89 ($P<0.05$) between shuttle-run predicted $VO_2$ peak and laboratory-measured $VO_2$ peak is in agreement with the findings of Ramsbottom *et al.* [13]. They reported a pooled r-value of 0.93 between $VO_2$ peak and the shuttle-run level attained. An inter-class correlation coefficient of 0.77 ($P<0.05$) was established between stair-run-derived PP and WAnT-derived 1s PP in the present study, a result that is in general agreement with the findings of Jacobs [8], who reported an *r* value of 0.84. The present result is also in concordance with the validity result (i.e. r=0.77) reported by Armstrong and Ellard [2], albeit, with untrained adolescent boys.

However, the high effect sizes detected (ES=0.86-1.5) for the differences between field-predicted and laboratory-determined aerobic and anaerobic performances demonstrated that even though field and laboratory tests may be designed to assess the same parameter of performance (i.e. aerobic or anaerobic), they each do not measure *exactly* the same thing. For example, the skill required of subjects in stair-running is not exactly the same as that required of sprint cycling, even both require the subjects to give a supra-maximal effort of a short duration in both tests. Similarly, even though running on the treadmill to volitional exhaustion and a run to fatigue on the 20 m-shuttle test both require cardiovascular endurance, the two exercise tasks are markedly different. It is therefore prudent for researchers to decide on which category of tests best suits their research purposes. Still as the shuttle-run test and the stair running tests have been shown to be adequately discriminatory in differentiating between those that are fit and those who are not, are low in cost and easy to administer, the use of such tests in large scale testing of PE trainee teachers is defensible, especially when they are used as motivational tools and for establishing performance standards for this specific population.

Bar-Or [3], introduced the notion of 'metabolic non-specialisation' when he used it to describe the performances of young people. He observed that in a subject cohort of young people, those who did well in endurance exercise also did well in short-duration exercise that demanded a high power output. The notion of 'metabolic non-specialisation' appears to be tenable when there is a significant and high correlation between aerobic and anaerobic performance variables. In the present study, the absence of a significant correlation between performance in the shuttle-run test and in the stair-running test suggested that 'metabolic non-specialisation' in the subjects was not present, a finding that is in concordance with the research results of Katch and Weltman [9]. However, whether the PE trainee teachers examined were 'metabolic specialists' cannot be discerned from the results of the present study and must await further research attention.

## Conclusion

The study provided important information about the aerobic and anaerobic field performances of PE trainee teachers in Singapore. Male subjects had greater predicted $VO_2$ peak values and stair-run-derived PP, even when differences in body mass was accounted for. Differences in body composition, levels of circulating testosterone in the blood as well as inherent cultural expectations between male and female subjects might explain some of the performance differences observed. However, additional studies are necessary to elucidate the issue further. The validity of using field performance tests for assessing PE trainee teachers in Singapore was confirmed. The shuttle-run test and the stair-running test may be viable alternatives to preferred laboratory tests when testing large cohorts of subjects, especially when expensive laboratory facilities and time are unavailable. However, it is prudent for researchers to decide on which category of tests best suits their research purposes. The notion of 'metabolic non-specialisation' was not supported in the present cohort of subjects studied.

## References

1. Armstrong N., J.Welsman (1997) Young People and Physical Activity. University Press, Oxford

2. Armstrong N., R.Ellard (1984) The measurement of alactic anaerobic power in trained and untrained adolescent boys. *Phys.Educ.Rev.* 7:73-79

3. Bar-Or O. (1983) Pediatric Sports Medicine for the Practitioner. Springer-Verl., New York

4. Chia M. (1998) Anaerobic Fitness of Young People. Doctoral Thesis, University of Exeter, UK

5. Chia M., N.Armstrong, D.Childs (1997) The assessment of children's anaerobic performance using modifications of the Wingate anaerobic test. *Pediatric Exerc.Sci.* 9: 80-89

6. Durnin J., J.Womersley (1974) Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16 to 72 years. *Br.J.Nutr.* 32:77-97

7. Inbar O., O.Bar-Or, J.S.Skinner (1996) The Wingate Anaerobic Test. Human Kinetics, Champaign, IL

8. Jacobs I. (1979) The effects of thermal dehydration on performance of the Wingate test of anaerobic power. Unpublished MSc thesis, 1-76. University of Windsor. Windsor, Ontario, Canada

9. Katch V., A.Weltman (1979) Interrelationships between anaerobic power output, anaerobic capacity, and aerobic power. *Ergonomics* 22:325-332

10. Matsudo V. (1996) Prediction of future athletic excellence. In: O.Bar-Or (ed.) The child and adolescent athlete. Blackwell Science, pp. 92-112

11. Margaria R., P.Aghemo, E.Rovelli (1966) Measurement of muscular power (anaerobi) in man. *J.Appl.Physiol.* 21:1662-1664

12. Murray R. (1992) Nutrition for the marathon and other endurance sports: environmental stress and dehydration. *Med.Sci.Sports Exerc.* 24:319-323

13. Ramsbottom R., J.Brewer, C.Williams (1988) A progressive shuttle-run test to estimate maximal oxygen uptake. *Br.J.Sports Med.* 22:141-144

14. Sawka M., M.Tahamont, P.Fitzgerald, D.Miles, R.Knowlton (1980) Alactic capacity and power, reliability and interpretation. *Eur.J.Appl.Physiol.* 45:109-116

15. Sproule J., C.Kunalan, M.McNeil, H.Wright (1993) Validity of 20-MST for predicting $VO_2$max of adult Singaporean athletes. *Br.J.Sports Med.* 27:202-204

Accepted for publication 31.01.2002