A Rhythmic Stepping Test for Assessment of Aerobic Power - A Preliminary Report

評估帶氧能力的台階測試－初步研究報告

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摘 要

帶氧能力或心肺功能的測試在體適能測試中佔了一個重要席位，其測試的結果正是一個好的耐力指標。台階測試是其中一個帶氧能力測試方法。本研究是根據Hatano's研究報告作為基礎。目的在於探討台階測試運用於本地人口的可靠性。此外，又探討以台階測試來估計最高耗氧量的準確性。

Introduction

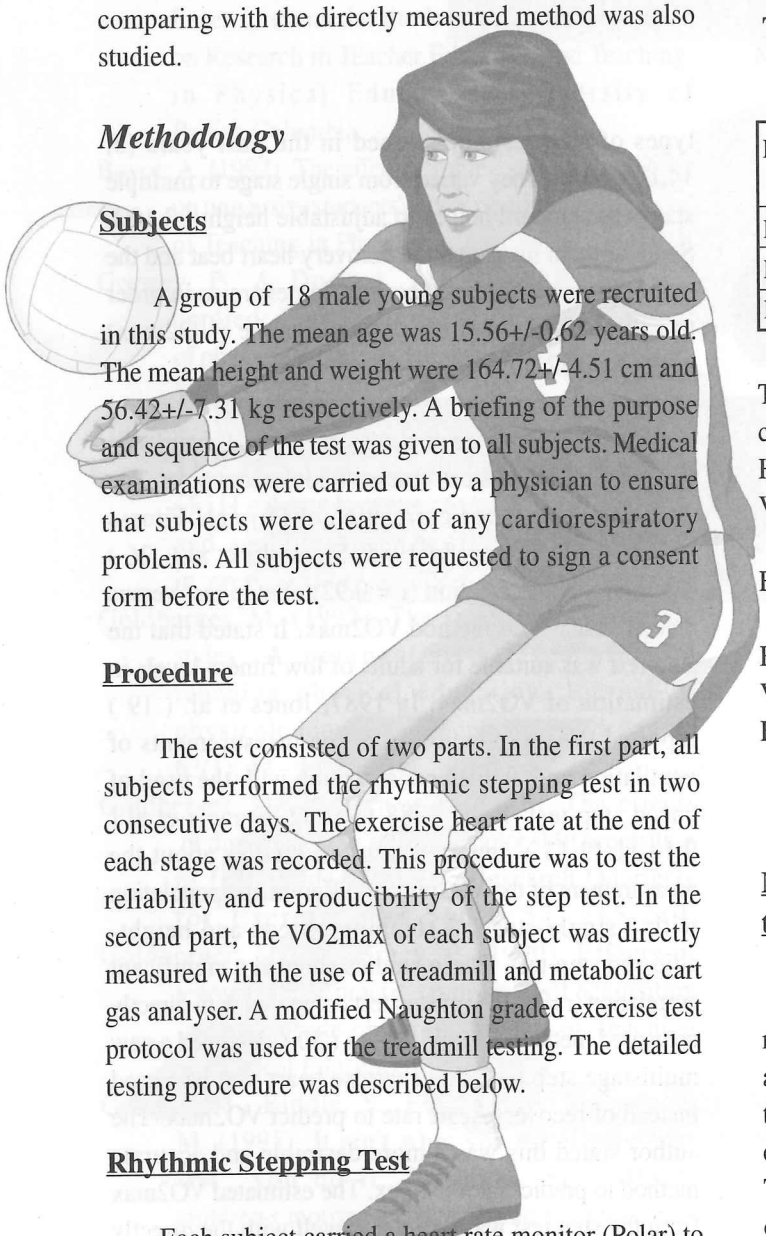
Measurement of aerobic power or cardiorespiratory fitness is a main component in any physical fitness assessment (7,22,24,25,29). The finding is a good indicator of endurance capacity. It also aids in designing safe aerobic exercise to patients with cardiorespiratory problems. Many exercise modes have been developed for the assessment of aerobic power (21,28,33). The common modes are treadmill, bicycle, shuttle run, rowing and step. The direct method to measure maximum aerobic power with the treadmill graded exercise protocol is usually regarded as the criterion test (8,31). There are other tests using different modes and requiring submaximal effort (4,16,20,27,33). The direct method is expensive and time consuming, and require a well-trained staff. A simple, inexpensive, reliable and valid testing tool is needed to assess the aerobic power for large population. Step test is one of the tools that might fulfill these criteria. In addition, it is highly portable, requires little or no calibration, uses large muscle group and is similar to people's daily activities. There were different types of step tests developed in the past years (5, 14,17,19,23). They varied from single stage to multiple stages or standard height to adjustable height (3,10). Some of them measured the recovery heart beat and the other measured the heart beat during exercise in order to estimate the maximal oxygen uptake (VO2max) (2,9,15,30,32).

In 1983, Banerjee et al.(3) used the Harvard step test to measure physical fitness of adolescent boys. The study showed a good correlation of Physical Fitness Index with VO2max. In 1985, Siconolfi et al.(26) reported high correlation (r = 0.92) of step test versus directly measured method VO2max. It stated that the step test was suitable for adults of low fitness levels in estimation of VO2max. In 1987, Jones et al. (19) reported the reproducibility of the measurements of ventilation and oxygen consumption with the used of paced step test. From 1988 to 1992, Francis et al (9,10,11,12,13) reported in a few studies about the measurement of the VO2max in different age population with a single-stage, 3 stepping speeds and height-adjusted step test. These studies showed a significant correlation (r=0.7-0.8) of step test compared with directly measured method. In 1995, Sykes (30) designed a new multistage step test. The exercise heart rate was used instead of recovery heart rate to predict VO2max. The author stated this was a more desirable and accurate method to predict the VO2max. The estimated VO2max from the step test was correlated well with the directly measured method. In 1995, Hatano (32) proposed a rhythmic stepping test for assessment of aerobic power.

The stepping exercise consisted of 3 climbing steps and each exercise lasted for 3 minutes.

The exercise heart rate recorded right after the test was again used to estimated the VO2max with a equation. Hatano concluded that the test has an acceptable level of accuracy and can be used in field testing of a large number of subjects.

This study was based on the experimental setting of Hatano's study. However, the technique in recording the heart rate was modified. This study used heart rate monitor to measure the heart rate during exercise. The objective of this study was to investigate the reliability of the step test with local population. Secondly, the accuracy of the step test in estimation of VO2max comparing with the directly measured method was also studied.



Methodology

Subjects

A group of 18 male young subjects were recruited in this study. The mean age was 15.56+/-0.62 years old. The mean height and weight were 164.72+/-4.51 cm and 56.42+/-7.31 kg respectively. A briefing of the purpose and sequence of the test was given to all subjects. Medical examinations were carried out by a physician to ensure that subjects were cleared of any cardiorespiratory problems. All subjects were requested to sign a consent form before the test.

Procedure

The test consisted of two parts. In the first part, all subjects performed the rhythmic stepping test in two consecutive days. The exercise heart rate at the end of each stage was recorded. This procedure was to test the reliability and reproducibility of the step test. In the second part, the VO2max of each subject was directly measured with the use of a treadmill and metabolic cart gas analyser. A modified Naughton graded exercise test protocol was used for the treadmill testing. The detailed testing procedure was described below.

Rhythmic Stepping Test

Each subject carried a heart rate monitor (Polar) to record their heart beat. Before the test, all subjects tried a few times on the step in order to familiar with the stepping sequences. The test consisted of three 3-min stages. A series of music with specific rhythmic tempos (each music being 3 minutes long) was produced by Yamaha Music Education Foundation. The stepping exercise consisted of 3 climbing steps of 2 stair steps and feet together for the third step and 3 steps of climbing down to stand with feet together (6 steps for 1 cycle of movement). The height of each step was 18 cm (regular stairs). Upon completing each 3 minutes long exercise, the subject's heart rate (beats/min) was taken by the heart rate monitor. The test was stopped if the heart beat exceeded 85% of maximal heart beat. The exercise intensity having been provided by use of ACSM's guidebook (23). The tempo and exercise intensity of the step test are showed in Table 1.

Table 1 : The Tempo and Exercise Intensity of Rhythmic Stepping Test

Music Number	Tempo (beat/min.)	Exercise Intensity (ml/kg/min)	Exercise Intensity (Mets)
No. 1	106	22.8	6.5
No. 2	120	25.9	7.4
No. 3	134	28.9	8.2

The estimated VO2max values at each stage were calculated by the use of Hatano's formula.

Hatano's Formula Estimated

VO2max = HRmax(beat/min) x VO2ex(ml/kg/min) / HRex (beat/min)

Estimated VO2max : Estimated maximum oxygen uptake (ml/kg/min)

HRmax : Maximum heart rate (beat/min)

VO2ex : Exercise oxygen uptake (ml/kg/min)

HRex : Exercise heart rate (best/min)

* Whereas assumed HR max = 220 - age (male)

HR max = 210 - age (female)

Measure the Maximal Oxygen Uptake with treadmill

Each subject carried a heart rate monitor (Polar) to record their heart beat. Before the test, all subjects tried a few times on the treadmill in order to familiarise with the test speed and gradient. A modified Naughton graded exercise test protocol was used for the treadmill testing. The protocol involved the use of constant walking speeds of 4.0 mph with increasing grade increments of 3.5 % every 2 minute to a point of maximal effort. The testing protocol is showed in Table 2.

Table 2 : Modified Naughton Graded Exercise Protocol (Speed = 4.0 mph)

Stage	Minutes	Grade (%)
1	0	0.0
2	2	3.5
3	4	7.0
4	6	10.5
5	8	14.0
6	10	17.5
7	12	21.0

Subjects were instructed to maintain a steady walking pace and avoid turning their head or trunk, causing loss of balance. Electrocardiography (ECG), heart rate (HR) and blood pressure (BP) were monitored throughout the test. They were encouraged to reach their maximum aerobic capacity. The heart rate and oxygen uptake were recorded at this point. Recovery included a 2 to 3 minute's period of walking (2.0 to 3.0 mph at 0% grade) follow by seated rest for 2 to 3 minutes.

Data Analysis

The reliability of Hatano's rhythmic stepping test was tested with the use of t-test for paired samples. The t-test also used to compute the difference between the directly measured VO2max and the estimated value from the step test. Pearson product moment correlations were also computed between the directly measured VO2max and the estimated value from the step test.

Results

Eighteen subjects were tested with the rhythmic stepping test in two consecutive days. The means and standard deviations of the exercising heart rate at each stage are showed in Table 3. There were no significant difference ($p>0.05$) between the two tests. The statistical results are showed in Table 4.

Table 3: Rhythmic Stepping Test (N=18)

	First Step Test			Second Step Test		
HR/min	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Mean	122.44	133.17	144.39	124.67	136.39	144.11
Standard Deviation	9.71	10.37	12.67	7.58	9.44	11.75

Table 4 : t-test for Paired Samples on theTwo Step Tests

	Stage 1	Stage 2	Stage 3
t value	-0.98	-1.77	0.15
p value	0.339	0.095	0.886

Table value df(17)(0.05)=2.11

The estimated VO2max values at each stage of the step test were calculated by the use of Hatano's formula. The means and standard deviations of the estimated VO2max are showed in Table 5. VO2max was also directly measured with a treadmill protocol. The means and standard deviations of the measured VO2max are also showed in Table 5. There were significant differences ($p<0.05$) in VO2max observed between the estimated and the directly measured method in all three stages of the step test. The statistical results are showed in Table 6. On the other hand, there were no significant correlation between the estimated and the directly measured values. The statistical results are showed in Table 7. The present step test under estimated the VO2max compared with the directly measured values. The average under estimation of VO2max at Stage 1, Stage 2 and Stage 3 were 20.77%, 18.14% and 14.87% respectively.

Table 5 : Estimated VO2max by Step Test and Directly Measured VO2 max by Treadmill (N=18)

VO2max (ml/kg/min)	Step test - Stage 1	Step test - Stage 2	Step test - Stage3	Treadmill
Mean	38.04	39.53	41.07	50.17
Standard Deviation	2.52	2.29	3.23	6.86

Table 6 : t-test for Paired Samples on the Estimated VO2max and Directly Measured VO2max

	Stage 1	Stage 2	Stage 3
t value	-7.11	-6.58	-5.47
p value	0.000	0.000	0.000

Table value df(17)(0.05)=2.11

Table 7 : Pearson Correlation Test on the Estimated VO2max and Directly Measured VO2max

	Stage 1	Stage 2	Stage 3
r value	0.0322	0.1691	0.1741
p value	0.899	0.502	0.490

Discussion

The direct measurement of maximal oxygen uptake with a graded exercise protocol is the most accurate method in the assessment of aerobic capacity. However, this testing is expensive, time consuming and sometimes cause adverse effect to subject. In addition, it is inapplicable to test large numbers of people at the same time. On the contrary, the step test is a simple, reliable and sub-maximal field test. The rhythmic step test proposed by Hatano is a good example. The stepping height is 18 cm that is a standard height of all regular stairs in building. The testing instructions and stepping patterns are recorded in a tape that facilitate both operators and subjects. The heart beat is recorded by heart rate monitor or simply by palpation. The 3 stepping speeds that suit people of all age and subjects with cardiorespiratory problems. The slow stepping speed is suitable for elderly people or person of lower exercise tolerance. And the faster stepping speed is suitable for younger people or person of higher exercise tolerance. Those advantages make the test an appropriate field test to assess the VO2max for subjects at all age.

In this current study, there was no significant difference ($p>0.05$) between the two step tests. The two step tests was carried out with the same group of subjects on two consecutive days. This finding was supported by other relevant studies (9,13,19,32). That mean subjects experienced the same physiological stimulation every time during the test. It suggested that the step test is a reliable and reproducible field test for aerobic capacity measurement.

There were significant differences ($p<0.05$) between the estimated VO2max of the step test and that of the direct measured VO2max in this study. Oxygen uptake measured at maximal exercise varied according to exercise modality. On the other hand, limitation existed when predicting VO2max from submaximal data. Brahler (5) reported significant greater VO2max value between VersaClimbing and rowing. Sproule (27) also reported significant difference between directly measured VO2max with the predicted value in 20 meter multistage shuttle run. Siconolfi (26) showed a 12% difference in predicted VO2max in step test. Francis (10,11,12,13) showed a +/-7% error in predicted VO2max with the height adjusted step test. Zwiren (33) stated that Queen College step test under estimated the VO2max by 5.3%. According to Hatano's study, it also showed a 6% under estimation of VO2max in the second stage of the step test. In the current study, under estimation of VO2max was also observed. The highest was 20.77% at stage 1 and the lowest was 14.87% at stage 3. In this study, correlations between the step test and the treadmill test on the measurement of VO2max are very low. Hatano (32) observed significant correlation ($r=0.704$) in his study. Siconlfi (26) and Kennon (9,13) also showed significant correlation ($r>0.75$) in their studies. These studies recruited subjects with different sex and age groups. As a resulted, a high correlation was expected because of the heterogeneity of the sample size. This effect was well explained by Nevill (1). In the current study, only male subjects were recruited. They were all approximately the same age group and similar body mass. A small correlation coefficient resulted in statistical test. In Cooper's 12-min run test, studies involved homogeneous and heterogeneous populations have yielded a wide range of correlation coefficients ($r=0.13$ to $r=0.90$) when comparing predicted VO2max with direct measured value. The correlation will improve if subjects of different sex and age groups are grouped.

In summary, the rhythmic step test used in this study is a safe, simple and reproducible field test for aerobic capacity measurement. It could be concluded that the present submaximal step test (Hatano) under estimated the VO2max and that stage 3 of this test is more appropriate for estimation of VO2max because the value is closer to the actual value. Accepting the limitation in predicting VO2max from submaximal data, the step test is an acceptable tool to measure the aerobic capacity of a large number of subjects when the laboratory is not available.

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