CONCURRENT VALIDITY AND RELIABILITY OF THE CHESTER STEP TEST AMONG ENDURANCE ATHLETES

BY

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APRIL 2010
We hereby recommend that the Honours Project by Mr. Yip Cho Wai entitled "Concurrent validity and reliability of the Chester step test among endurance athletes" be accepted in partial fulfillment of the requirements for the Bachelor of Arts Honours Degree in Physical Education And Recreation Management.

_________________________        _____________________
Dr. Tom Kwok Keung        Prof. Chow Bik Chu
Chief Adviser        Second Reader
DECLARATION

I hereby declare that this honours project "Concurrent validity and reliability of the Chester step test among endurance athletes" represents my own work and had not been previously submitted to this or other institution for a degree, diploma or other qualification. Citations from the other authors were listed in the references.

_______________________
Yip Cho Wai

Date: 23rd April, 2010
ACKNOWLEDGEMENTS

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_____________________________
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Date: 23rd April, 2010
ABSTRACT

The Chester step test (CST) is a submaximal test to assess cardiovascular fitness by many health sectors in community. However, there was no previous research related to the accuracy of the test among endurance athletes. So the study was aimed to examine firstly, the concurrent validity of the CST among endurance athletes, secondly the test-retest reliability of the CST. Nine endurance athletes (N = 9) who were the representative of the Hong Kong Baptist University team members, were selected to participate in this study. All subjects were asked to participate in the CST on two occasions and a treadmill maximal test. The reliability analysis (Cronbach’s Alpha = 0.96) showed a reliability between test and re-test, and dependent t test indicated there was no significant mean difference (t(8) = -0.30; p > 0.05) between the result of CST on two occasions. The concurrent validity of the CST was examined between the result of treadmill maximal test and that of CST, the result showed there was no significant correlation between actual VO2max from treadmill maximal test
and predicted VO$_{2\text{max}}$ from the Chester step test ($r = 0.41$, $p > 0.05$). The finding showed there was reliability between the test and re-test of CST, but the validity of the CST among endurance athletes was questioned.
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Chapter 1

INTRODUCTION

Cardiovascular fitness is the effectiveness of the circulatory and respiratory system to supply oxygen when performing physical activity continuously (American College of Sports Medicine [ACSM], 2010). Shephard (1994) stated in some vigorous activities, the ability to sustain a moderate duration is termed as aerobic fitness, which is the main physiological determinant for continuing heavy work. Another similar term is called aerobic capacity, which is the ability of the cardiovascular system to transfer the oxygen for the use of working muscles. Various benefits could be obtained from aerobic exercise included enhancement in cardiovascular function, lower chance in coronary artery diseases and reducing mortality (ACSM, 2010). For competitive level, Shephard (1994) emphasized aerobic capacity is critical to success in competitions with more than half an hour.

Measurement of fitness becomes more popular on health status checking or rehabilitation. ACSM (2010) pointed out
the health assessment is helpful on development and evaluation exercise program. Besides, people could set up attainable goals easier and reduce the cardiovascular risks. For specified population such as elderly, the fitness test could provide objective information to plan different activity program for different patients (Purath, Buchholz & Kark, 2009). Within the scope of physical education, Welk (2008) recognized the assessment could promote physical activity by maintaining their interest and gave beneficial result to assist home and community support for physical education. Also, teachers could use the measures for providing feedback to children and rising parents’ awareness on children’s health. For endurance athletes, the assessment of cardiovascular fitness could reveal the initial performance or improvement.

Various methods for measuring aerobic power were developed nowadays. Maud and Foster (1995) classified all methods into two categories, which namely maximal tests and submaximal tests. Maximal tests mostly give a more accurate value of maximum oxygen uptake (VO₂max) than do submaximal
tests. Treadmill is the machine frequently used and similar values of VO\textsubscript{max} could be directly measured despite of different treadmill protocol. For the submaximal tests, the rationale is using heart rate response to predict VO\textsubscript{max}, and other measures such as blood pressure, workload or rating of perceived exertion (RPE) could be an informative index to estimate VO\textsubscript{max} too. For example, submaximal cycling test together with the use of RPE was done (Eston & Williams, 1988), while Buckley, Eston and Sim (2000) also used similar test to assess validity and reliability in production of exercise intensity. Step testing is another inexpensive submaximal test. ACSM (2010) stated the principle is using heart rate response in recovery phase to predict corresponding aerobic fitness level. Chen et al. (2006) also observed heart rate recovery as an indicator of cardio-respiratory fitness, the faster the pace of recovery, the higher fitness level of subjects. Other submaximal tests include walking and running tests, cycle ergometry test and other field tests.

The Chester step test (CST) is a submaximal test with
multistage design, with heart rate and RPE are the monitoring variables throughout the whole test. Buckley, Sim, Eston, Hession and Fox (2004) introduced the history of the CST was originally developed by Kevin Sykes at University College Chester. The test aimed to estimate maximal aerobic power and was widely used by firemen’ fitness assessment all around the world. The physiological rationale of aerobic capacity prediction is based on linear relationship among exercise intensity, VO\textsubscript{2}max and exercise heart rate. The test is most importantly, safely controlled by monitoring heart rate and RPE (Sykes). So CST was also frequently used by many health sectors in community and even suitable for elderly and rehabilitant.

**Statement of problem**

The treadmill maximal test is best validated test that frequently used to estimating VO\textsubscript{2}max, the correlation coefficients of the related equation for Bruce protocol was 0.977 and the standard error of estimation was less than 3.5
mL·kg$^{-1}$·min$^{-1}$ (Maud and Foster, 1995). Thus the treadmill maximal test is generally recognized to be valid test for all population includes endurance athletes. However, there are various demerits to be found in the test. The equipment cost valuable price such as motor-driven treadmill and electrocardiogram. Also, the sudden increase in workload consumes significant amount of energy, which may affect the training schedule of athletes. Maximal tests often require greater cardiovascular stress than submaximal tests. Zeni, Hoffman and Clifford (1996) also did a research to state the treadmill machine need higher level of energy expenditure and aerobic demands than other exercise machines. Meanwhile the set up and monitoring testing protocol require specialized technicians’ help. Submaximal test like the Chester step test could be a good substitute for the assessment of aerobic fitness level among endurance athletes due to the light exercise intensity, adaptable nature and easy to conduct (Sykes & Roberts, 2004). However, there was no finding related to accuracy of the Chester step test on endurance athletes
before, through the Chester step test was found to be a good measure of cardiovascular fitness on general population, but it might not be valid in endurance athlete.

**Purpose of study**

Therefore, the purpose of study was to examine firstly, the concurrent validity of the Chester step among endurance athletes, secondly, the reliability of the Chester step test.

**Significance of the study**

Endurance athletes participate in sports with high aerobic demand, the major characteristic is the long duration of competitions. Shephard (1994) pointed out the enhancement of maximal oxygen uptake determines the result of competitions. So the athletes often measure VO\(_2\)\text{max} since it regarded as “gold standard” for assessment of cardiorespiratory fitness (Maud and Foster, 1995). The aim of study was to examine and validate the Chester step test to see if it really gives accurate and reliable measures among endurance athletes. Many people could
participate in the test at the same time; meanwhile the test is inexpensive and portable. The test could help the coaches assess their athletes in a more efficient and economic way. Furthermore, the effect of assessment on training schedule would be minimized since only low efforts are paid on the test.
Chapter 2

REVIEW OF LITERATURE

The present study was to examine the concurrent validity and reliability of the Chester step test (CST) among endurance athletes. A summary of related literature, that was important to reveal the idea and rationale of the study, was shown in this chapter. The chapter focused on five aspects: they were (a) the importance of aerobic fitness; (b) parameters for assessing aerobic fitness; (c) explanation of the Chester step test and previous research; (d) physiological trait of endurance athletes; and (e) summary.

The importance of aerobic fitness

Aerobic fitness is one of the major components in health related fitness. ACSM (2010) also stated there was strong evidence from large-scale observational studies to support the negative relationship between physical activities and various cardiovascular diseases such as hypertension and stroke.
The burden of blood pressure was decreased since it reduced resting systolic and diastolic blood pressure. A research was done (Eisenmann et al., 2005) on the association of aerobic fitness and risk factors of cardiovascular disease. The most obvious finding was the level of aerobic fitness level inversely related to level of blood pressure as well as blood lipids; it was applicable to both male and female subjects. Roberts (1996) had the similar idea that aerobic exercise makes heart muscle stronger and beats less eventually, which resulted in lower blood pressure. Cornelissen and Fagard (2005) figured out the training induced decrease in blood pressure in resting was 3.0/2.4 mm Hg ($P_{0.001}$) and in daytime was 3.3/3.5 mm Hg ($P_{0.01}$). Shephard and Astrand (2000) found that the changes of systolic blood pressure and diastolic blood pressure were -7 mmHg and -6 mmHg respectively after 12 weeks exercise program. Ritvanen, Louhevaara, Helin, Halonen & Hänninen (2007) also stated people with good aerobic fitness had lower blood pressure at rest and during stress conditions.

On the other hand, respiratory function could be improved
by lower minute ventilation and myocardial oxygen cost (ACSM, 2010). Rochester (2003) conducted a research on effect of training on pulmonary disease patients. The result was improved exercise endurance regardless of high or low exercise intensity, and high intensity workout led to physiological gain in aerobic fitness by reduction in ventilation. Also, improvement of respiratory muscles was found in both strength and endurance, the muscles included limb muscles and chest muscles (Gore, 2002). People sustained high degree of ventilation would affect the respiratory muscle more likely become fatigue (Shephard, 1994). Thus the aerobic exercise program is necessary for pulmonary disease patients.

Moreover, ACSM (2010) and Robert (1996) recognized aerobic exercise could decrease the level of anxiety and depression and thus increase the feeling of well-being. The fit people could escape from tension through exercise, meanwhile they had more vitality as more energy was available to use. Scientific research (Ritvanen et al., 2007) was done to show the effectiveness of aerobic fitness on human stress
reduction. The conclusion was aerobic fitness lessening muscle tension and preventing tight muscles. Working performance would be improved after exercise program, Shephard (1994) supported the idea that aerobic exercise program enable workers against minor illness and working more hours. Also, the chance of mistake caused by fatigue was lower (Robert, 1996). Various benefits could be obtained from aerobic exercise program for working population.

The most significant effect of aerobic exercise is the increased VO₂max. Physical training with aerobic exercise program improved VO₂max by 5-30%, greater enhancement was found in lower fitness population and cardiac patients (Gore, 2000), and Robert (1996) also stated 30% was the maximum improvement in VO₂max after twelve week of exercise program. ACSM (2010) also mentioned central and peripheral adaptation lead to increase in VO₂max after regular exercises. Baquet, Praagh & Berthoin (2003) investigated there was 8-10% peak improvement for adolescents after exercise with intensity greater than 80% of maximum heart rate.
Parameters for assessing aerobic fitness

Various parameters influencing aerobic exercise performance such as maximum oxygen uptake (VO$_{2\text{max}}$), lactate threshold (LT), exercise economy and oxygen uptake kinetics (Jones & Carter, 2000), the former two are regularly used in research studies. VO$_{2\text{max}}$ is significant in assessing aerobic fitness and a key factor for endurance performance (Shephard & Astrand, 2000). Robert (1996) also regarded it as the best measure of cardiovascular fitness. Many researchers like Baque, Praagh & Berthoin, 2003; Buckley et al., 2004; Sykes & Roberts, 2004, used VO$_{2\text{max}}$ as variable to indicate the aerobic fitness level.

Blood lactate threshold is another common testing parameter. Especially for elite level, the induced change from training would be more obvious when compared with VO$_{2\text{max}}$ (Gore, 2000). Jones and Carter (2000) also pointed out LT is powerful predictor to observe the fitness level and the LT is positively linked to endurance performance. Researchers like Maud and Foster (1995) and Shephard and Astrand (2000) had similar idea
that the accumulation of blood lactate was caused by doing long duration exercise. Tomlin and Wenger (2001) did a research on effect of aerobic exercise, the result showed the physiological gain was facilitating lactate removal.

Heart rate is an often being measured parameter in various assessment tests. Buck (2002) and Shephard (1994) mentioned heart rate was a key figure to reveal aerobic fitness level. For exercise tests with increasing intensity, heart rate raise as linear relationship of power output and oxygen consumption. Submaximal test might use certain percentage such as 85% of age-predicted maximum heart rate as ending point of test (Hoffman, 2006). Tremendous aerobic tests used heart rate on prediction on aerobic fitness level like Sundstedt, Hedberg, Jonason, Ringqvist, Brodin, & Henriksen, 2004; Buckley, Eston, & Sim, 2000; Eston, & Williams, 1998; Elliot, Abt, & Barry, 2008. Since aerobic training will eventually lower submaximal heart rate (Zavorsky, 2000), plenty of studies were conducted based on this rationale.
Explanation of the Chester step test and previous research

The Chester step test (CST) is a kind of submaximal test designated to assess aerobic fitness under safe and practical situation (Sykes). There are three assumptions on the CST procedure: (1) linear relationship between heart rate and VO₂, (2) maximal heart rate and VO₂max occurred simultaneously, (3) maximal heart rate is age-predicted heart rate which was equal to 220 minus subject’s age. The linear relationship is drawn from the value of submaximal heart rate in each stage until reaching subjects’ age-predicted maximum heart rate and finds the corresponding VO₂max afterwards. The intensity of CST is adjusted according to increasing rhythms ranging from 15 steps per minute to 35 steps per minute that guided by metronome or verbal instructions from cassette tape. Sykes added the height of step is adjustable to different population with wide range of ages, abilities and conditions. The ending point of test is 80% of age estimated maximal heart rate and/or RPE of 14 on Borg’s scale.

The previous researches on CST were mainly focus on its
validity and reliability. Sykes and Roberts (2004) compared the result of predicted VO₂max from CST and direct measurement of VO₂max from treadmill maximal test. The overall correlation \((r = 0.92; \ p<0.001)\) was high, meanwhile the correlation in females \((r = 0.95, \ P<0.001)\) was higher than that of males’ group \((r = 0.87, \ P<0.001)\). But another similar study conducted by Buckley et al. (2004) questioned the prediction validity of CST as it could underestimate the actual VO₂max by 9 mL·kg⁻¹·min⁻¹ (19%) and overestimate the actual VO₂max by 5.5 mL·kg⁻¹·min⁻¹ (11%). Concerning on the reliability, Sykes and Roberts (2004) found the mean difference between repeated predicted measures was -0.7 mL·kg⁻¹·min⁻¹ while the mean difference on separate days was 4.5 mL·kg⁻¹·min⁻¹, so the test-retest reliability was found to be good. Buckley et al. also showed that the test-retest reliability was acceptable with the 95% LoA was ±3.7 mL·kg⁻¹·min⁻¹. Another research (Elliot et al., 2008) was examining the influence of arm dynamics on heart rate of CST.
Physiological traits of endurance athletes

Most endurance athletes need high aerobic and anaerobic capabilities (Gore, 2000) since the former one is critical for long duration events while the later one is better suited for high energy demand (Evans, 1997). Long distance male runners might have VO₂max as much as 80 mL·kg⁻¹·min⁻¹ (Hoffman, 2006). Beside outstanding VO₂max, the maximum heart rate of endurance athlete need longer time to reach, for example, Zavorsky (2000) listed endurance collegiate athletes had lower maximal heart rate by 3.7 to 4 beats/min than sedentary and physically active person (p < 0.05). Moreover, the cardiac output for highly trained endurance athletes was around 34 to 42 L·min⁻¹, which was a high figure to ease oxygen transport (Sundstedt et al., 2004). Also, cardiac hypertrophy was a common phenomenon among endurance athletes, especially there was greater left ventricular diastolic dimensions (Shephard, 1994). Shephard and Astrand (2000) added endurance athletes had greater left ventricular chamber size and modest wall thickening which would enhance blood pressure system. Another
physiological trait is the body size since it is one of the selective indicators essential for endurance performance; most of them were in mesomorphy category (Shephard and Astrand, 2000). Gore (2000) stated endurance athletes have lower absolute and relative fat mass than other types of athletes. Loucks (2007) gave an example that marathon runners usually wanted to reduce body weight and fat, since excess body mass negatively influenced running performance.

**Summary**

Aerobic fitness was accepted as one of the basic criteria for health in general population, meanwhile it was even play an important role on deciding the result of endurance sport. Thus assessment of aerobic fitness was a good way to trace and follow up the effectiveness of initial exercise program and health status. Although the measurement of VO$_2$max directly was considered as gold standard on aerobic fitness power (Hoffman, 2006), but it required expensive equipment, more preparation, space and laboratory personnel. When direct
measurement of VO₂max was not possible, submaximal test on predicting the VO₂max would be an alternative method. So assessing the parameters such as heart rate, blood lactate and RPE were frequently used. The CST was one of the convenient submaximal tests focusing on heart rate and RPE; previous research was done on assessing the validity on general population like university students (Buckley et al., 2004). However, the validity of CST on predicting VO₂max on endurance athlete with generally higher level of VO₂max and lower level of exercise heart rate remained in question.

**Research Hypothesis**

The hypotheses of the current study were as follow:

**Concurrent Validity**

There would be significant correlation between the predicted VO₂max from the CST and the actual VO₂max from maximal treadmill test.
Reliability

The Chester step test would be a reliable test for measuring the cardiovascular fitness of the endurance athletes.
Chapter 3

METHODS

The purpose of this study was to examine the concurrent validity and reliability of the Chester step test (CST) among endurance athletes. This chapter was divided into several parts mentioned below: (a) subjects; (b) procedures; (c) research design; (d) definition of terms; (e) data analysis; (f) delimitations; and (g) limitations.

Subjects

A group of endurance athletes (n = 9) was selected to participate in this study. Male consisted of six meanwhile female consisted of three. All of them were endurance athletes from the Hong Kong Baptist University team members. They had regular training 2 times a week, with no less than 4 hours training every week. The subjects are aged from 20 to 24 years. The whole study was consisted of two tests; the Chester step test and treadmill maximal exercise test. The subjects were required to participate in both tests. Informed consent
(Appendix A) was signed by the subjects before the beginning of research and their health status was screened by completing the PAR-Q form (Appendix B) before the tests (ACSM, 2010).

**Procedure**

All subjects were asked to engage in Chester step tests on two occasions and treadmill maximal test within two weeks. The order of all tests was randomly selected so as to eliminate the ordering effect. Both CST and treadmill maximal test were held in The Dr. Stephen Hui Research Centre for Physical Recreation and Wellness in the Hong Kong Baptist University.

**Research Design**

To examine the concurrent validity of the Chester step test (CST), correlation analysis was done between the predicted VO₂max from Chester step test and the actual VO₂max from treadmill maximal test to indicate if it was an accurate measure of maximal oxygen uptake on endurance athlete. The reliability of the Chester step test was assessed by computing
the repeatability of the Chester step test.

**Chester step test**

The following was the procedure of Chester step test (Sykes). The test was done using a 30-cm aerobic step as it was suitable for subjects under 40 years old with regular physical exercise. The subjects listened to the rhythms from a metronome for correct stepping beat. For level 1 which was the starting stage, the metronome beat was at 15 steps per minute for 2 minutes and heart rate and rating of perceived exertion (RPE) were recorded at the end of stage. For the further stages, the step increased 5 steps per minute for every stage, so level 2 stage consisted of 20 steps per minute, level 3 stage is 25 steps per minute and the final stage (level 5) is 35 steps per minute with heart rate and rating of perceived exertion were recorded at each stage. The design of this step test was modified by changing the end point of test, it raised to 90% of age predicted heart rate maximal and RPE 17 rather than stopped at heart rate of 80% of predicted maximum (220 -
age). It could possibly get the predicted maximal oxygen uptake data from higher stage of CST (Buckley et al., 2004).

Each stage heart rate point was plotted on a graph (Appendix C) and connected to form a line segment. The line segment was then extended up and to the intersection with the horizontal line representing predicted maximum heart rate. A vertical line perpendicular to the intersection point drawn down to the x-axis showed the corresponding aerobic capacity.

Heart rate monitor was used to measure exercise heart rate instead of manual palpation on radial artery as it was more valid and reliable (Buck, 2002).

**Treadmill maximal test**

The VO₂max test was done on a treadmill, using modified Astrand protocol (Heyward, 2006) which speed was keep constant at 5-8 miles per hour and increasing the gradient by 2.5% for every 2 minutes. The speed was set according to the 70% of predicted maximal heart rate during the warm up stage. Also, the speed allowed summoning exhaustion during the test. The
maximum duration of test was around 14 minutes. Subjects were familiarized with walking and running on a treadmill for 5 minutes. The data of expired gas, carbon dioxide production, oxygen consumption and heart rate were under supervision. At the last 10 seconds of each stage, heart rate and RPE were recorded. And adjustment of gradient was made at the same time with the agreement of subjects. Criteria for VO\(_2\)max being reached were that two of the following should be met: (i) heart rate reached predicted maximum (220-age), (ii) respiratory exchange ratio reached 1.15, (iii) RPE reached 18/20 on the Borg scale and (iv) subject had obvious signs of exhaustion and volitional fatigue. (Heyward, 2006)

**Definition of Terms**

The following terms were operationally defined especially for this study:
Health-related fitness

Health related fitness contributes to the development of health and increases the functional capacity of the body, the major components includes cardiovascular endurance, body composition, muscular endurance, muscular strength and flexibility (Robert, 1996).

Cardiovascular endurance

The ability of the circulatory and respiratory system to supply oxygen during sustained physical activity (ACSM, 2010).

Aerobic work

The aerobic work is defined as activities using large muscle group at an intensity that can be sustained for a long period of time in which the body is able to provide sufficient energy aerobically (Robert, 1996).
**Maximum oxygen uptake (VO2max)**

It is an indicator to measure cardiovascular system delivers how much amount of adequate oxygenated blood to working muscles. So it could be reflected by amount of oxygen transported to working muscles and utilization of oxygen by the muscles during exercise (Heyward, 2006).

**Target-zone heart rate**

It refers to the heart rate necessary for maximum development of cardiovascular endurance. It ranges from 70% to 85% of the maximal heart rate (Robert, 1996).

**Maximal tests**

It refers to the tests that estimate better maximum oxygen consumption from performance on standardized protocols on the treadmill, cycle ergometer, or arm ergometer (Maud & Foster, 1995).
**Submaximal testing**

It refers to tests that require the subjects who are performing the exercise tests on a particular mode at a known output that is less than their maximal effort (American College of Sports Medicine [ACSM], 2008).

**Concurrent validity**

The concurrent validity is made when two measures of the same variable are obtained within a time period. One measure is applied criterion while the other one is to be validated. The degree of statistical relationship between two measures determines the accuracy of the test being examined (Berg & Latin, 2008).

**Reliability**

Reliability is the ability of a test to yield consistent and stable results among different trails of tests over a period of time (Berg & Latin, 2008).
Data Analysis

This study aimed to examine the concurrent validity and reliability of the Chester step test. The following were the statistical (null) hypotheses of the study:

1. There would be no significant correlation between the performances of the treadmill maximal test and that from the Chester step test among the subjects.

2. There would be significant mean difference between the result of test and re-test of the CST.

Statistical analysis was run by the “Statistic Package of Social Science” Version 15.0 (SPSS Inc., Chicago, TL). In this study, descriptive data included mean and standard deviation (SD) were shown in mean ±SD. Pearson Production Moment Coefficient of Correlation (r) was used to examine the correlation between the results from treadmill maximal test and results from the Chester step test, as a result, to determine the concurrent validity. Moreover, Cronbach’s Alpha of reliability analysis and dependent t test was computed to
measure the reliability of the Chester step test. An alpha level of 0.05 was used to indicate statistical significance in all above tests.

**Delimitations**

The scope of the study was delimited to the following conditions:

1. The subjects of this study were delimited to endurance athletes from the Hong Kong Baptist University team members with at least 4 hours of training every week.

2. The total number of subjects was nine which six people were male and three people were female.

3. The age of subjects ranged from 20 to 24.

4. The Chester step test on two occasions and treadmill maximal test were carried on separate days within two weeks.

5. Both Chester step test and treadmill maximal test were conducted in the laboratory of Dr. Stephen Hui Research Centre for Physical Recreation and Wellness in the Hong Kong Baptist University.
Limitations

The followings were limitations that might interfere with the results of study:

1. Variables included dietary pattern, daily activities and pervious injuries were uncontrollable.

2. The performance of subjects might be influenced by their motivation and effort.

3. The data and results of each subject were collected at different dates and times.

4. The results could only apply for the subjects who take part in this study.
Chapter 4

ANAYSIS OF DATA

Results

Nine endurance athletes were invited to participate in this study, 6 of them were male while 3 of them were female. They had regular training on their specify sports which included long distance running (n = 6), soccer (n = 1), swimming (n = 1) and orienteering (n = 1) with at least 4 hours of regular training every week. All subjects were representative of university team member on their specific sport in the Hong Kong Baptist University. This study aimed to examine firstly, the concurrent validity of the Chester step test (CST) among endurance athletes, secondly, the reliability of the Chester step test among endurance athletes. All subjects were voluntary engaged to participate in the treadmill maximal test for one time and the Chester step test for two times within 2 weeks.

The descriptive data of physical characteristics of the subjects were shown in Table 1.
Table 1 Physical characteristics of the endurance athletes (N = 9)

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Mean</th>
<th>±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>20 – 24</td>
<td>22.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>157 – 175</td>
<td>168.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Weight (kg)</td>
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<td>58.0</td>
<td>7.4</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>17.8 – 22.9</td>
<td>20.4</td>
<td>1.5</td>
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<td>Weekly training</td>
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<td>3.0</td>
</tr>
</tbody>
</table>

Besides the physical characteristics of the subjects, the descriptive statistics of subjects’ performance in the treadmill maximal test and the Chester step test on two occasions were shown in Table 2.
Table 2 Descriptive statistics of subjects’ performance in the VO2max test, CST1 and CST2 (N = 9)

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Mean</th>
<th>±SD</th>
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<tr>
<td>VO2max test</td>
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<td>55.8</td>
<td>9.5</td>
</tr>
<tr>
<td>(mL·kg⁻¹·min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CST1</td>
<td>43.0 – 65.0</td>
<td>51.1</td>
<td>7.4</td>
</tr>
<tr>
<td>(mL·kg⁻¹·min⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CST2</td>
<td>44.0 – 68.0</td>
<td>51.4</td>
<td>9.0</td>
</tr>
<tr>
<td>(mL·kg⁻¹·min⁻¹)</td>
<td></td>
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</tbody>
</table>

VO2max test: Maximal treadmill test

CST1: Chester step test (1st occasion)

CST2: Chester step test (2nd occasion)

Furthermore, the analysis of data would be revealed in the following two parts: (i) Reliability of the CST, and (ii) Concurrent validity of the CST.

(i) The reliability of the CST

Cronbach’s Alpha was used in the reliability analysis. CST in 1st occasion (CST1) and CST in 2nd occasion (CST2) were
selected in the analysis. The result was shown in Table 3.

Table 3 The reliability analysis result (N = 9)

<table>
<thead>
<tr>
<th></th>
<th>Cronbach’s Alpha</th>
<th>N of Items</th>
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<tbody>
<tr>
<td>Result of CST1 and CST2</td>
<td>0.96</td>
<td>2</td>
</tr>
</tbody>
</table>

Paired sample *t* test was also used to examine the mean difference between the CST in 1st occasion and CST in 2nd occasion, the computed result was shown in Table 4.

Table 4 The dependent *t* test of two CST (N = 9)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>SEE</th>
<th><em>t</em></th>
<th>df</th>
<th>Sig.(2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paired t test</td>
<td>-0.33</td>
<td>3.32</td>
<td>1.10</td>
<td>-0.302</td>
<td>8</td>
<td>0.771</td>
</tr>
</tbody>
</table>

The computed value showed that there was reliability between the test and retest (Cronbach’s Alpha = 0.96). Also, the critical *t* value for two-tailed test with 8 df is 2.31, the computed dependent *t* ratio was -0.30 and smaller than the critical *t* 2.31. It indicated there was no significant mean
difference between the CST on two occasions. So the null hypothesis “there would be significant mean difference between the result of test and re-test of the CST” was rejected.

(ii) The concurrent validity of the CST

As the CST was reliable in the above analysis, the CST2 was used in examining the validation. Pearson correlation between the result of treadmill maximal test (VO₂max test) and the CST on 2nd occasion (CST2) was used to examine the concurrent validity of the Chester step test. The Pearson correlation coefficient was shown in Table 5.

Table 5 Pearson’s correlation test between all subjects’ performance in the maximal treadmill test (VO₂max test) and the CST on 2nd occasion (CST2) (N = 9)

<table>
<thead>
<tr>
<th></th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation between VO₂max test and CST2</td>
<td>0.412</td>
<td>0.270</td>
</tr>
</tbody>
</table>
Figure 1 showed the relationship of between the result obtained in treadmill maximal test and result recorded in the CST on 2\textsuperscript{nd} occasion for all nine subjects.

Figure 1

Scatter plots of the result from maximal treadmill test and result from the CST on 2\textsuperscript{nd} occasion (N = 9)

Scatter plots of VO2 maximal treadmill test’s result and Chester step test’s result

By using the Pearson product moment coefficient of
correlation, the results revealed that there was a positive relationship \((r = 0.41)\) between the result recorded in treadmill maximal test (VO2max test) and the Chester step test (CST2). However, the computed value showed that the correlation between actual VO2max from treadmill maximal test and predicted VO2max from Chester step test was not significant \((r = 0.41, p > 0.05)\). And according to the scatter plots in Figure 1, it also shown there was no significant correlation between the actual VO2max from treadmill maximal test and predicted VO2max from Chester step test. Hence the null hypothesis “there would be no significant correlation between the performances of the treadmill maximal test and that from the Chester step test among the subjects.” was not rejected.

**Discussion**

The purpose of the study was to examine firstly, the concurrent validity of the Chester step test (CST), secondly, the reliability of the CST. In the discussion section, it would be divided into three parts: (a) Concurrent validity of CST
in endurance athletes, (b) Factors that affect the performance of the test, and (c) Reliability of the CST.

**Concurrent validity of CST in endurance athletes**

There were previous studies accessing the validity of the CST on cardiovascular fitness, the research conducted by Sykes and Roberts (2004) found a high overall correlation ($r = 0.92; P < 0.001$) between VO$_\text{2max}$ and the results of the CST. However, the subjects recruited by Sykes and Roberts (2004) were general population with wide range of ages and abilities (mean age 30.6±9.7 years; range 18 – 52 years). But referring to this study, the Pearson's correlation coefficient ($r = 0.412$) indicated a positive relationship but the result was not a statistically significant level. So the result was different to Sykes and Roberts (2004). On the other hand, it agreed with the conclusion made by Buckley et al. (2004) that the VO$_\text{2max}$ prediction validity of CST is questioned. The big difference of this study and the study conducted by Sykes and Roberts (2004) was the subjects. The subjects in this study were
endurance athletes, the mean difference between the VO2max and the predicted VO2max from CST is $4.3 \pm 10 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, which mean the CST is generally unable to predict the actual VO2max in this study.

_Factors that affect the performance of the test_

Various factors could influence the result of test, and the result of the CST could attribute to basic assumptions of the test which might result inaccurate measurement. Sykes and Roberts (2004) and Buckley et al. (2004) also discussed the potential sources of error which included the prediction of maximum heart rate, linear relationship of heart rate and VO2 uptake and the stepping mechanical efficiency.

The age - prediction of maximum heart rate was shown as following equation: $HR_{max} = 220 - \text{age (yrs)}$. ACSM (2008) stated the formula has a standard error of estimation associated with it of about $\text{SEE} = \pm 12 \text{ bpm}$. Hence 67% of subjects would within range of age predict maximum heart rate $\pm 12$, but there was still 33% of subjects might have their maximum heart rate out
the range. Similar idea was reported by Heyward (2006) that when submaximal value were extrapolated to an age predicted maximum heart rate, considerable error of VO\textsubscript{2}max could ranging from \(\pm 10\%\) to \(\pm 15\%\). As the predicted VO\textsubscript{2}max from CST is determined from maximum heart rate, thus large standard deviation of maximum heart rate would result inaccurate predicted VO\textsubscript{2}max.

The assumption that the heart rate and VO\textsubscript{2} responses should be at linear relationship was a concern (Buckley et al., 2004). The changing response of heart rate at different stage could have variety rather at a constant increasing, which might result in non-linear or curvilinear relationship. Heyward (2006) also mentioned the linear relationships between heart rate, oxygen uptake and work intensity hold for light to moderate workloads, but the relationship might become curvilinear at heavier workloads. Furthermore, the CST needs to draw “visual line of best fit” which might not be accurate to find out the VO\textsubscript{2}max. Also, researcher might find difficulty to draw or determine the accurate “line of best fit”.
The stepping mechanical efficiency could affect the result of recorded heart rate. The stepping rate was one of the influencing factors that affect the exercise oxygen cost as well as recorded heart rate (Sykes and Roberts, 2004). Some subjects might not be familiar with faster tempo; the rapid changing of rhythm could lead to wrong stepping rate that eventually made the subjects nervous and higher heart rate. Verbal instruction was given to minimize the effect. Another concern was the step height. Buckley et al. (2004) stated choice of step height was critical to the predicted result. In this study, only 0.30m step was used as all subjects were under the 40 years old with regular physical exercise. Heyward (2006) also pointed out energy expenditure increased by 1.04 kcal/min when bench height rose from 15.2cm to 20.3cm. However, there were difference between subjects’ height and leg length as well as weight, which indicated their stepping mechanical efficiency could be different as higher height subjects could step with lesser energy expenditure relatively to lower height subjects.
The design of treadmill maximal test and CST through also accessing cardiovascular fitness, but their measuring variables has a contrast. The treadmill maximal test require subjects to attain their maximal and exhausted level, and data of VO_{2max}, RER and heart rate could displayed on the computer screen. For the CST, the main accessing variable was the exercise heart rate at submaximal level. The main concern was endurance athletes' performance not solely dependent on exercise heart rate, other factors such as gas exchange ability and exercise efficiency were also critical. Hence the physiological contribution might be neglected during the CST.

Psychological factors would also affect the performance of endurance athletes on both tests, especially their motivation and excitement level. During the graded exercise test, motivation was critical for them to sustain the test for longer time to get the value of VO_{2max}. However, the subjects could stop the test because of volitional fatigue; the test was terminated due to safety concern (ACSM, 2008). It was vital to assume the subjects had given maximum effort,
but it was not testable. Verbal encouragement was given to stimulate their motivation and longer tolerance. The CST was using record heart rate at every stage to determine the “line of best fit”, so any psychological fluctuation would affect the exercise heart rate. Once the subjects were excited, the recorded higher heart rate would eventually underestimate the actual predicted VO\textsubscript{2max} value.

Uncontrollable daily activities would cause impact upon the result of tests. Subjects’ dietary pattern, resting or sleeping hours, training and exercise hours, injury or sickness were unobservable. Moreover, it was difficult to ensure all these factors were kept constant before every test for each subject or among different subjects. Pretest instructions were given to all subjects one day prior to subjects such as avoid caffeine or medicine intake on testing day, avoid vigorous exercise 24 hours before testing days and adequate sleeping hours (6 – 8 hours) on the night before the testing days (ACSM, 2008) to minimize the effects.
Reliability of the CST

The current study of CST showed it was a reliable test. The mean difference between two trials was -0.3 mL·kg\(^{-1}\)·min\(^{-1}\), which was close to the finding from Sykes and Roberts (2004) that the mean difference between repeated predicted measures was -0.7 mL·kg\(^{-1}\)·min\(^{-1}\). Buckley et al. (2004) stated similar statistics, the test-retest reliability was little intertrial bias about -0.8 mL·kg\(^{-1}\)·min\(^{-1}\). The difference was at acceptable level. Moreover, Sykes also reported the reproducibility and reliability of the CST was good (r = 0.9).

In this study, the Cronbach’s Alpha of reliability analysis between two CST in two occasions was 0.96, the result shows the two trials of CST was highly correlated. Moreover, dependent t test also indicated there was no significant mean difference (t = -0.30; p = 0.77) for the CST result in two trials. The current study and previous studies also shows the test-retest reliability of CST.
Chapter 5

SUMMARY AND CONCLUSIONS

Summary of Results

The current study was aimed to examine firstly, the concurrent validity of the CST in endurance athletes, secondly, the reliability of the CST. Nine endurance athletes from the Hong Kong Baptist University team members were participated in this study. They specialized in traditional endurance sport training include long distance running (n = 6), soccer (n = 1), swimming (n = 1) and orienteering (n = 1) with at least 4 hours of regular training every week. All subjects were voluntary participated a treadmill maximal test and the CST in two trials. All tests were conducted in The Dr. Stephen Hui Research Centre for Physical Recreation and Wellness in the Hong Kong Baptist University. All tests were conducted on separated days within two weeks. The testing results were collected and analyzed by the Statistical Package of Social Science (SPSS) for windows 15.0 version. Pearson Product Moment Coefficient of Correlation (r), reliability analysis
and dependent sample t test were used with the alpha level being set at 0.05.

The results of this study were summarized as follows:

1. There is no significant correlation between the actual VO$_2$max from treadmill maximal test and predicted VO$_2$max from Chester step test ($r = 0.41; p = 0.27 > 0.05$). The result indicates a low index of accuracy of the CST on predicting the VO$_2$max value in endurance athletes. The validity of CST on endurance athletes is questioned in this study.

2. The CST is a reliable test (Cronbach’s Alpha = 0.96) for accessing cardiovascular fitness, and there is no significant mean difference ($t(8)=-0.30; p > 0.05$) between test and re-test.

Conclusion

The findings show that there is low correlation between the results of treadmill maximal test and results from the CST. When using the CST on endurance athlete, the low
correlation indicates the index of accuracy of CST is weak in this target population. However, the analysis of reliability is far encouraging than its validity. There is no significant mean difference among two trials in the endurance athletes. The CST is a reliable test but not an accurate test for accessing the oxygen uptake data in this study.

**Recommendation of Further Study**

Based on the current study, the following recommendations are presented for the further study:

1. The sample size should be enlarged so as to conduct a more representative result.

2. The validity on gender difference would be a good area to investigate with a representative sample size.

3. The study should include more number of subjects in different type of endurance sports for accessing the difference of validation.
4. One more trial of treadmill maximal test should be conducted in order to obtain a more accurate VO2max value.

5. It is better to access the validity of CST by using different step height.
REFERENCES


Informed Consent for Exercise Testing

I hereby voluntarily give consent to engage in a fitness test. I understand that the cardiovascular fitness test will involve progressive stages of increasing effort and that at any time I may terminate the test for any reason. I understand that during some tests I may be encouraged to work at maximum effort and that at any time I may terminate the test for any reason.

I understand there are certain changes which may occur during the exercise test. They include abnormal blood pressure, fainting, disorders of heart beat, and very rare instances of heart attack. I understand that every effort will be made to minimize problems by preliminary examination and observation during testing.

I understand that I am responsible for monitoring my own condition throughout testing, and should any unusual symptoms occur, I will cease my participation and inform the test administrator of the symptoms. Unusual symptoms include, but are not limited to: chest discomfort, nausea, difficulty in breathing, and joint or muscle injury.

The test allow assessing my physical working capacity and to appraise my physical fitness status. The results are used to prescribe a safe, sound exercise program for me. Records are kept strictly confidential unless my consent to release this information.

Finally, I have read the foregoing carefully and I understand its content. Any questions which may have occurred to me concerning this informed consent have been answered to my satisfaction.

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
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<tbody>
<tr>
<td>Witness</td>
<td>Date</td>
</tr>
</tbody>
</table>
APPENDIX B

PAR-Q FORM

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
2. Do you feel pain in your chest when you do physical activity?
3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?
5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
7. Do you know of any other reason why you should not do physical activity?

If you answered YES to one or more questions,
Talk with your doctor by phone or in person before you start becoming much more physically active or before you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.
- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

If you answered NO to all questions,
You may start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
Take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to become physically active. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

Note: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name: __________________________
Signature: ________________________

Signature of Parent: __________________________
or Guardian for participants under the age of majority: __________________________

Date: ________________________
Physical Activity Guide to Healthy Active Living

Physical activity improves health.

Every little bit counts, but more is even better — everyone can do it!

Get active your way — build physical activity into your daily life:

- at home
- at school
- at work
- at play
- on the way...

...that's active living!

Get Active Your Way — Every Day — For Life!

Activities that cumulate 10 minutes of physical activity every day to strong health or improve your health.

As you progress, more activities you can do. For example, 10 minutes, 1 hour per week. At least 20 minutes of physical activity, 20 minutes per week.

- Walking
- Cycling
- Swimming
- Yoga
- Dancing
- Aerobics
- Tai Chi
- Gardening

You can do it. — Getting started is easier than you think.

Physical activity doesn’t have to be hard. Physical activity this your daily health.

- Walking: Walk when you can — get the activity when you can — the walk counts.
- Aerobic activity for any period of time:
- Endurance: Endurance for any period of time:
- Strength: Strength for any period of time:

Benefits of regular activity:

- Lowered blood pressure
- Increased VO2 max
- Improved bone density
- Improved range of motion
- Improved balance
- Improved flexibility
- Improved mood
- Improved quality of life

Fitness and health professionals may be interested in the information below:

The following companion forms are available for use by contacting the Canadian Society for Exercise Physiology (address below):

- The Physical Activity Readiness Medical Examination (PARmed-X) — to be used by doctors with people who answer YES to one or more questions on the PAR-Q.
- The Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy) — to be used by doctors with pregnant patients who wish to become more active.

References:


For more information, please contact the:

Canadian Society for Exercise Physiology
205-185 Somerset Street West
Ottawa, Ontario
Canada K1A 0L2

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been reviewed by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gedbilli (2002).
APPENDIX C

Data recording form (CST)
## APPENDIX D

Data recording form (Maximal treadmill test)

### Treadmill Maximal Test (Modified Astrand Protocol)

Name: ______________________ (English) ______________________ (Chinese)

Age: _____  
Gender:  M / F

Height: _______  
Weight: _______  
BMI: _______

Type of endurance exercise: ___________________

Average training hours per week: ____________

Date of treadmill maximal test: ______________

<table>
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<tr>
<th>Stage no.</th>
<th>Time (minute)</th>
<th>Gradient</th>
<th>Heart rate</th>
<th>RPE</th>
<th>RER</th>
<th>VO2 max</th>
</tr>
</thead>
<tbody>
<tr>
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**Vo2 max = ____________**