Research Report

Cardiovascular endurance levels of Asian Games 2006 bound Filipino elite athletes

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ABSTRACT

Objective: To assess the endurance levels of Filipino Asian bound athletes (road cyclists, boxers, Olympic rowers and long distance runners) in terms of maximal oxygen uptake, heart rate max and blood lactate response. ***Methodology:*** All elite Asian bound athletes of the Philippine National Team, participating in endurance events such as boxing, canoe and kayak, cycling, long distance running (athletics) and Olympic rowing are eligible to participate in this study. Anthropometric measurements such as height and weight were taken on the testing day. A series of sports specific battery of endurance test were conducted to measure maximal oxygen uptake, blood lactate and heart rate max. ***Results:*** Endurance testing of the subjects yielded the following results: in terms of peak VO_2 Olympic rowers have the mean peak value of 64.14 ml/kg/min, long distance runners: 63 ml/kg/min canoe and kayak: 59.23 ml/kg/min, boxing:57.13ml/kg/min,cyclists:52.07,l/kg/min. As for blood lactate cyclists mean peak blood lactate at 8 mmol/ L, boxers: 10.5 mmol/ L, long distance runners: 11.2 mmol/ L. Canoe and kayak: 14.4 mmol/L, Olympic rowing: 15.9 mmol/L. In terms of heart rate max, Olympic rowers have a mean peak value of heart at 189.4 bpm, canoe and kayak: 185.5 bpm, boxing: 178.3 bpm, long distance running: 174 bpm, cycling: 165.5 bpm. ***Conclusion:*** The researchers were able to assess the endurance levels of Filipino Asian Games bound elite athlete (boxers, road cyclists, canoe and kayak athletes, Olympic rowers and long distance runners) in terms of heart rate (average heart rate responses, maximum heart rate and percent predicted heart rate max achieved), oxygen consumption, blood lactate response and peak VO_2. This study also was able to provide endurance level values and establish a set of data in terms of aerobic capacity of elite Filipino endurance athletes

Keywords: *aerobic capacity (non-mesh), asian games (non-mesh), elite athletes (non-mesh), endurance events (non-mesh)*

INTRODUCTION

Endurance is a term that describes two separate related concepts namely muscular endurance and cardio respiratory endurance. Whereas muscular endurance refers to the ability of individual muscles, cardiovascular endurance relates to the body as a whole system. Specifically, it refers to the body's ability to maintain prolonged rhythmical exercise. This type of endurance is typified by cyclist, distance runner and endurance swimmer who can complete long distances at fairly fast pace. Cardio respiratory endurance is highly related to the development of cardiovascular and respiratory systems, and thus aerobic development.[1]

Used in this sense, an athlete with a better level of endurance might be expected to be able to sustain a level of activity with less fatigue than an athlete with lesser endurance. Endurance is one of the aspects that must be improved and assessed in sports like rowing, boxing, cycling and running.

Cardiovascular endurance, or aerobic capacity, is the ability to exercise continuously for extended periods without tiring, and is an important component of many sporting activities. A person's aerobic fitness level is dependent upon the amount of oxygen which can be transported by the body to the working muscles, and the efficiency of the muscles to use that oxygen.[2]

Assessment of cardiovascular endurance considers different parameters and these include VO_2, maximum heart rate and lactate threshold. VO_2 is the amount (expressed as a volume or V) of oxygen used by the muscles during a specified interval (usually 1 minute) for cell metabolism and energy production. Maximum oxygen consumption (VO_2max) is the maximum volume of oxygen that can be used per minute, representing any individual's upper limit of aerobic metabolism which can be expressed as an absolute amount (again as a volume per minute) or as a % of each individual's personal maximum (%VO_2max).[3] It is considered as the physiological variable that best describes the capacities of the cardiovascular and respiratory systems. It is also considered the gold standard of cardiovascular, pulmonary, and muscle cell fitness. The value for VO_2 max is determined by the capacity of the cardiorespiratory system to deliver oxygen to the tissues. In order to say that an individual achieves his or her VO2max, the following criteria have to be met: (1) there is a plateau in oxygen uptake with a further increase in work rate; (2) a respiratory exchange ratio of greater than 1; (3) a blood lactate concentration of greater than 8 mmol per liter five minutes after recovery; and (4) a heart rate that is 85% of the maximum heart rate. Peak VO_2, the highest level of VO_2 elicited during an exercise test to exhaustion, is considered a more appropriate index for determining the endurance exercise potential in endurance athletes.[4, 5]

Another important measure of cardiovascular endurance is maximum heart rate achieved. Heart rate max is the highest number of heart beats per minute (bpm) when pushing the body as hard as possible. The most accurate way of determining your individual HRmax is to have it clinically measured in a maximal exercise stress test in a laboratory. HRmax is a useful tool for determining the intensity of exercise. [6]

Aside from VO2 and heart rate, another physiologic index of cardiovascular endurance is the measure of blood lactate. Blood lactate is the form that lactic acid takes in our blood stream and lactic acid is a by-product of anaerobic metabolism. Anaerobic metabolism is a chemical process used to produce energy within our bodies and is most often used during sprinting, weight lifting and any other activities of high intensity and short duration. Blood lactate is a good indicator of the rate of energy production from the anaerobic energy system and it can be used to monitor intensity and adaptation to exercise. [7] At low levels of exercise intensity, blood lactate is low but as exercise intensity increases, lactate increases exponentially. The point where lactate rapidly increases is termed the lactate threshold and is often used by elite athletes to monitor their training.[7]

These are valid and readily available measures of cardiovascular endurance. It is important to measure athletes' cardiovascular endurance to serve as baseline data and likewise, to monitor improvement in performance. Thus, the objectives of this study were to:

1. Assess the cardiovascular endurance levels of Filipino Asian Games 2006 bound elite athletes in terms of heart rate and VO2 responses during exercise test, HR max achieved, percent predicted HR max achieved, blood lactate at termination and peak VO_2; and
2. Compare endurance levels of Filipino Asian bound athletes across different endurance events.

METHODOLOGY

Participants

All Filipino Asian Games 2006 bound elite athletes of the Philippine National Team, were eligible to participate in this study. The list of participants for the study was obtained from the official roster of elite endurance athletes authorized by the Philippine Olympic Committee and Philippine Sports Commission. Those with existing cardiovascular diseases and problems, respiratory illness, and other medical conditions based from the Pre Participation Physical Examination (PPPE) conducted by the Philippine Center for Sports Medicine, Sports Physiology Unit of the Philippine Sports Commission and athletes with existing injuries and undergone surgery for the last 6 months were excluded from the study.

Preparation before testing:

The sport specific endurance tests and outcome measures to be used were identified. Ethical Approval was secured from the Research Center for the Health Sciences of the Faculty of Medicine and Surgery. After the initial set of preparations, letters were sent to the respective coaches and athletes and subject recruitment was finalized.

An inter-tester and intra-tester reliability testing for height measurements using only one subject for all the assessors was conducted prior to testing to ensure accuracy of measurements.

Subject preparation:
Upon selection of all the participants included in the study, a meeting was scheduled to orient the coaches and athletes, after which, the consent forms were distributed and collected.

Warm Up:
A summary of the testing procedures is shown in Figure 1. Once the athletes entered the laboratory, height and weight measurements were obtained using a stadiometer and a digital weighing scale. Polar heart rate monitors were attached to the athletes' xiphisternal area, to monitor heart rate responses, together with the Cosmed Fitmate metabolic gas analyzer, to measure oxygen consumption, and maintained during the entire testing procedure. The pre – warm up heart rate and blood lactate were obtained and recorded. For warm – up, the boxers and canoe and kayak athletes used the treadmill with 3.5 kph speed during first five minutes and was increased to 5 kph during the next five minutes. For the cyclists, a 10 minute warm up was also given using a 53 x 21 gear on their bikes attached to a roller. The Olympic rowers used the concept II Ergometer for their warm up. After the tenth minute, heart rate and blood lactate were taken immediately and recorded.

Testing proper:
For the boxers and kayak and canoe athletes, the Bruce protocol was used to maximally exhaust the athletes. The Bruce protocol is a standardized multistage treadmill test for assessing cardiovascular health. The athletes walk, jog or run on an uphill treadmill in a graded exercise test. Every three minutes, the speed and incline of the treadmill are increased. There are seven stages and only very fit athletes can complete all seven stages.[8] The athletes were instructed to stop only at the point of volitional fatigue or made to stop by the assessors if signs of exercise intolerance were noted. In each stage of the protocol reached, heart rate and oxygen consumption were taken and recorded. At test termination, the immediate values of heart rate, blood lactate and oxygen consumption were taken. Heart rate and blood lactate were also taken during the 3^{rd}, 5^{th} and 7^{th} minute during the recovery of the subjects at 3.5 kph. VO_2 peak and heart rate max were then identified and recorded.

For the cyclists, a graded gear cycling protocol was used to measure their cardiovascular endurance. The protocol is composed of seven stages; each stage is set for three minutes, with increasing gear ratio and maintained cadence of 100 rpm. In each stage, the blood lactate and heart rate of the subjects were taken. The succeeding stages (e.g. 8^{th}, 9^{th}, and 10th) were introduced with the same gear ratio as with the 7th stage but with an additional cadence of 10 rpm per stage. Like in the Bruce protocol, the athletes were instructed to stop only at the point of volitional fatigue or made to stop by the assessors if signs of exercise intolerance were noted. In each stage of the protocol, heart rate, blood lactate and oxygen consumption were taken and recorded. At test termination, the immediate values of heart rate, blood lactate and oxygen consumption were taken. The heart rate and blood lactate were also taken on the 3^{rd}, 5^{th} and 7^{th} minute during the recovery of the subjects with gear ratio set back to 53 x 21. VO_2 peak and heart rate max were then identified and recorded.

For the Olympic rowers, the 2000 meter submaximal test was used.[9] This test involves simulation of a race. The rowers were required to complete a distance of 2000 m using the concept II rowing ergometer, in the shortest possible time. Every 250 meter distance reached until completion of the 2000 meter distance, heart rate and oxygen consumption were obtained and recorded. Since the test is submaximal, all athletes finished the eight stages of the test. At test termination, the immediate values of heart rate, blood lactate and oxygen consumption were taken. The heart rate and blood lactate were also taken during the 2^{nd}, 4^{th} and 6^{th} minute during the recovery of the subjects. Based from the heart rate and oxygen consumption recorded every 250m, a predicted VO_2 value was extrapolated using the age predicted target heart rate as basis.

Data Analysis
One way ANOVA was used to analyze reliability test for height measurements. Descriptive statistics (means and standard deviations) was used to analyze the collected data. This type of statistical test summarizes large group of data and is used when all the information about the population is known.

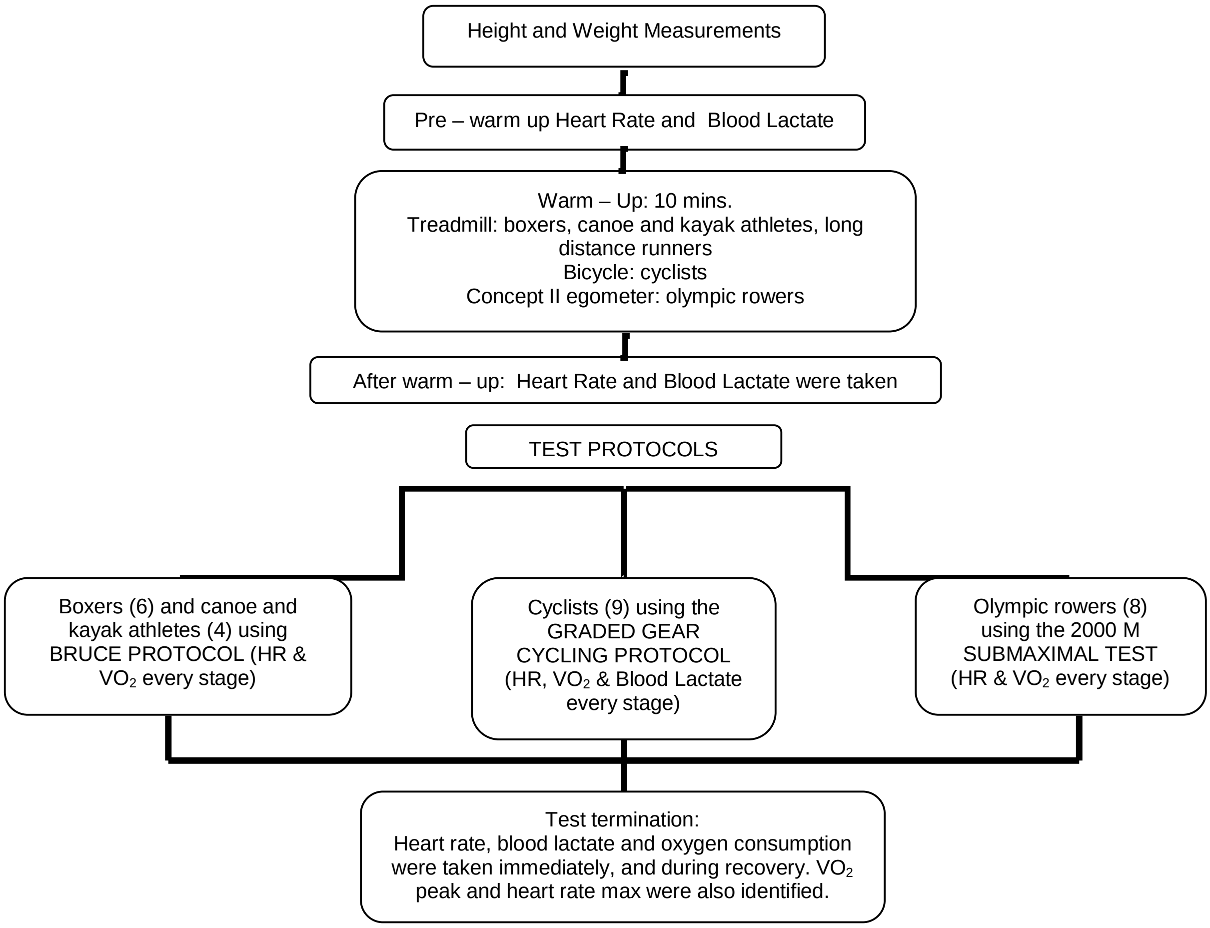

Figure 1 – Flow of Procedures

RESULTS

Reliability testing for height measurements yielded a *p value* of 0.468469, which is less than the *F critical value* of 4.256495, indicating that there was no significant difference among the height assessors.

A total of 28 athletes (24 males and 4 females) composed of six boxers, four canoe and kayak athletes, nine cyclists, eight Olympic rowers and one long distance runner were included and assessed. Tables 1 and 2 show the results for male and female athletes

DISCUSSION

Boxing is estimated to be 70-80% anaerobic and 20-30% aerobic type of sport. [10] Boxing's work and rest ratio is approximately 3:1. The nature of boxing requires athletes to sustain power at a high percentage of maximal oxygen uptakes (VO_2max) (often above lactate threshold, producing high levels of blood lactate leading to premature fatigue). The primary aim of conditioning for boxing is to delay the onset of fatigue by increasing tolerance of lactic acid build-up, increasing the ATP and CP, to improve efficiency of oxygen use, and to improve recovery between intense bursts of activity. [10]

The average VO_2max of present elite boxers was observed to be 54.6 and 61.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in Indian junior and senior boxers respectively. Similar study on elite Indian boxers showed VO_2max value of 54.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Moreover, some other study observed VO_2max of 55.8 $ml \cdot kg^{-1} \cdot min^{-1}$ in Greek national boxers, 56.6 $ml \cdot kg^{-1} \cdot min^{-1}$ in Hungarian boxers and 64.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in French boxers. [10]

Table 1. Results of Male Athletes expressed in Means and Standard Deviations

	Boxing (N = 6)	Canoe/ Kayak (N = 4)	Cycling (N = 8)	Olympic Rowing (N = 5)
Age	23.17±2.40	19.25±1.89	30.25±3.69	30.60±3.78
Height (cm)	170.20±6.98	163.50±5.07	167.88±8.06	180.40±4.67
Weight (kg)	61.60±7.02	63.75±4.27	65.86±9.82	78.60±4.67
Heart Rate Responses during Exercise Test (bpm)	143.94 ±8.59	144.06 ±6.92	140.85±16.72	173.33±10.08
VO2 Responses during Exercise Test (mlO2/kg/min)	37.3 ±1.08	39.24±4.11	37.4±7.96	50.77±5.85
HR Max (bpm)	179.33±7.03	186±9.49	166.63±8.52	189.4±3.78
Blood Lactate at Test Termination (mmol)	10.48±3.29	14.93 ±1.67	8±4	15.88±2.21
Percentage of Predicted HR Achieved	91.13±4.04	92.63 ±4.10	87.8 ±3.82	N/A
Peak VO2 (mlO2/kg/min)	57.13 ±4.10	59.23±6.36	52.71 ±5.95	64.14±7.34

**** For Olympic rowing, a 2000m submaximal test was used. Peak VO2 was based from an extrapolated data of heart rate and VO_2 responses. Maximum heart rate for maximal test was not obtained and percentage of predicted heart rate achieved cannot be computed.*

Table 2. **Results of Female Athletes expressed in Means and Standard Deviations**

	Age	Height (cm)	Weight (kg)	Mean HR Responses during Exercise Test (bpm)	Mean VO2 Responses during Exercise Test (mlO2/kg/min)	Mean HR Max (bpm)	Blood Lactate at Test Termination (mmol)	Mean Percentage of Predicted HR Achieved	Peak VO2 (mlO2/kg/min)
Cycling (N = 1)	29	163	55	149.8	38	177	9	92.67	46.9
Olympic Rowing (N = 3)	21.33 ±1.15	165.67 ±2.08	59.33 ±8.50	172.71 ±4.80	37.18 ±3.22	198.67 ±1.15	13.867 ±1.27	N/A	49.7 ±8.35

**** For Olympic rowing, a 2000m submaximal test was used. Peak VO2 was based from an extrapolated data of heart rate and VO_2 responses. Maximum heart rate for maximal test was not obtained and percentage of predicted heart rate achieved cannot be computed.*

As compared with our local elite boxers, results showed that a mean peak VO_2 value of 57.13 m/kg/ min was reached, which is higher as compared with the elite Indian, Greeks, and Hungarian boxers, and slightly lower as compared with elite French boxers. These data show that our local elite boxers are up to par with other elite foreign boxers in terms of cardiovascular endurance.

Kayaking is a sporting activity characterized by exceptional demands on upper body performance.[11] A successful kayaker requires high aerobic power, high anaerobic energy yield and great upper body muscle strength.[11, 12] Elite kayakers have been reported to possess a total body maximal oxygen uptake of 5.30-5.60 $l.min^{-1}$(53 -56 ml/kg/min)[12] which is slightly lower as compared to a 59.23 ml/kg/min peak VO_2 value achieved by our local elite kayakers. Examination of the best Swedish kayakers suggests that individual, international successful performance at 1000 m distance is accomplished when maximal oxygen uptake exceeds 54ml/kg/min. Similarly, during a 1000 m race, a peak oxygen consumption corresponding to at least 49ml/kg/min is desired.[12]

Elite kayakers are also characterized by exhibiting great strength, anaerobic capacity and endurance of those muscles contributing to propelling the kayak.[11,12] Metabolic characteristics favoring endurance of muscles involved in both shoulder extensors and arm flexors are increased in kayakers. The low rate of fatigue development found is also consistent with the demonstration of a high percentage of high oxidative, slow twitch muscle fibers in the deltoid muscle of paddlers. It can be questioned whether a sufficient level of the specific muscular strength required can be evoked by intense paddling training only or whether complementary resistance training is needed and is an effective aid in improving kayak performance. [12]

Cycling is an excellent form of exercise which allows for effective training and adaptations in both anaerobic and aerobic energy systems, as well as improvements in the cardio respiratory system. In a study of elite cyclists, VO_2 max of cyclist from treadmill, bicycle and velodrome, they were able to measure the VO_2max of trained cyclists on the treadmill (means +/- SD = 54.7 +/- 6.3 ml kg-1 min-1), while riding a bicycle on a velodrome track at 100 rpm (53.7 +/- 7.8) and on the bicycle Ergometer at 60 rpm (62.4 +/- 8.1): VO_2max being the highest in the latter case (p less than 0.05). As compared with our local elite cyclists who had their test on their own bikes, a peak VO_2 value of 52.07 ml/kg/min was achieved which is lower than 62.4 ml/kg/min. [13]

In another study, seven male cyclists [maximal O2 consumption (O2) 58-69 ml · kg1 · min1] each

Table 3. **Mean Values for Olympic Rowers**					
	Power (watts)	HR (b/min)	VO2 (L/min)	VO2 (ml/kg/min)	Lactic Acid (mmol/L)
Males, 35	467	189	6.25	70.9	17.4
Females, 25	310	190	4.31	58.6	13.1

**** Hagerman F. Physical Characteristics of Elite Rowers-1992 U.S. Olympic Team, 1992*

completed 11 randomized trials on a cycle ergometer at a workload requiring 90% maximal VO_2. Current record shows that male elite cyclists have a VO_2max of 75 ml/kg/min while females have a record of 56 ml/kg/min. On the other hand, the greatest cyclists, such as Lance Armstrong, Miguel Indurain and Chris Boardman, have records ranging from 80-90 ml/kg/min. [14]

Olympic Rowing is one of the original sports in the modern Olympic Games. Rowing is a total body workout but may look like an upper body sport. It is one of the few athletic activities that involve all of the body's major muscle groups.[15] Rowing is an endurance sport that finishes at a speed of up to 10 metres a second. Crews cover the middle 1000 metres at about 40 strokes per minute, but, over the first and last 500 metres, shift up a gear to as many as 47.[15]

The data represent mean values for the group. Even without adjustment for the developments over the last decade, the data in the table below show values that are among the highest reported among endurance athletes.[15] (Table 3)

Rowing force and boat velocity correlate to maximal oxygen uptake (VO_2) which reaches 6.0-6.61.min-1 (65-70 ml.min-1. kg-1). [15] As compared with our local elite rowers, a slightly lower value for predicted peak VO_2 was extrapolated at 64 ml/kg/min for males and 49.7 ml/kg/min for females. In turn, the VO_2 during a race is related to slow-twitch fibers content of the muscles, also to the aerobic-anaerobic threshold (AAT) and inversely related to the maximal blood lactate level.[15]

Olympic rowers are the tallest and the heaviest of all the athletes. Since the boat used in the sport accelerates as it moves in reaction to the sweeping arc of the oar, acceleration will be proportional to force times time. Therefore the rower must achieve an optimal combination of high stroke power and long stroke length. This combined high force and long impulse duration requirement tends to select for rowers of specific size and length. [15]

In our study, the Olympic rowers still had the highest heart rate response to exercise test having a mean value of 173.33±10.08 and blood lactate at test termination with a mean value of 15.88±2.21. In a study on rowing, it was stated that glycolytic processes also provide an important part of the energy supply with elevated lactate levels measured as high as 15 - 17mmol/l at the end of competition. Increased lactate exchange and removal abilities in highly trained rowers allowing sustained performance at high power. Theoretically, in athletes with similar aerobic capacity, those with improved ability to remove lactate would be capable of rowing and maintaining higher intensities.[16]

CONCLUSION

This study establishes a set of data on the endurance levels and in terms of aerobic capacity of elite Filipino endurance athletes. As mentioned, this can now be used by the coaches as a basis to assess and compare our local elite athletes with their foreign counterparts in terms of aerobic capacity. Coaches and athletes may also use the data obtained to monitor training and serve as a basis for improvement.

In terms of maximal oxygen consumption across different endurance events, canoe and kayak athletes has the highest peak VO_2 with a value of 59.23 ml/kg/min. followed by boxers and cyclists, with a peak VO_2 value of 57.13 ml/kg/min and 52.71 ml/kg/min, respectively. However, a kayak ergometer was not available for the canoe and kayak athletes which maybe a more specific for the test. Olympic rowers yielded peak VO_2 values of 64 ml/kg/min. However, the obtained values were not compared with the first three sporting events since they fall under the limitations of the study. In terms of the test protocols, submaximal test was used for Olympic rowers due to coach's hesitance for maximal test and the need for a simulation race test.

Thus, it is recommended that further studies be done, particularly on other endurance sports, involving more athletes and utilizing maximal protocols for endurance tests specifically on Olympic rowing.

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