AEROBIC POWER AND ANAEROBIC THRESHOLD OF MALE ROWERS

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in the
Theory of Coaching

by
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ABSTRACT

TITLE OF THESIS: Aerobic Power and Anaerobic Threshold of Male Rowers

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The purpose of this study was to investigate the endurance component of off-season rowing performance in male rowers before and after an 8-week training period. Specific attention was given to laboratory assessment of aerobic power (AP) and anaerobic threshold (AT) as they were affected by the above training period.

A single subject case study research design was employed, which involved pre- and post-training tests, of seven male rowers of national and provincial calibre. Following the pre-training test, individualized training programs were designed involving continuous and interval endurance training. The training intensity for continuous training (CT) and interval training (IT) was based on a percentage below (AT -10% $\dot{V}O_2$ max) and above (AT +10 to 25% $\dot{V}O_2$ max) the subject's AT. The training intensity was monitored through heart rate count. The training was carried out on rowing ergometers (Concept II), 3 times per week, each session lasting 50 to 60 minutes. After the training period, $\dot{V}O_2$ max $L \cdot min^{-1}$ and $\dot{V}O_2$ $Ml \cdot kg^{-1} \cdot min^{-1}$ at AT increased in all subjects between

1.8% and 22.9% and -4.2% to 16.3%, respectively. As well, the maximum rowing ergometer performance, power output, maximum workload, and time before reaching AT increased.

High levels of AT among oarsmen are attributed to the specific nature of training regimens which may have increased the oxidative capacity of muscle fibers and the cardiorespiratory transport system. Measurement of HR at AT could provide the coach and the oarsman with an objective method of monitoring the intensity of training. These results demonstrate that the AT in rowers is profoundly influenced by endurance training.

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INTRODUCTION

Statement of the Problem

The purpose of this study was to investigate the endurance component of off-season rowing performance in male rowers before and after an 8 week training period. Specific attention was given to laboratory assessment of "aerobic power" and "anaerobic threshold" as they were affected by the above-mentioned training period.

Significance of the Study

High performance in the sport of rowing is only achieved through systematic training that is structured according to known scientific laws and principles. This high performance is a result of the development and interaction of the following basic components: endurance, strength and power, technique, flexibility, co-ordination and motivational factors.

Rowing has long been considered one of the most demanding continuous endurance activities in competitive sport (Hagerman & Lee, 1971; Hagerman, Addington & Gaensler, 1972; Hagerman, Gault, Connors & Hagerman, 1975a; Hagerman, Whitney, Geensler & Geensler, 1975b; Hagerman, Connors, Gault, Hagerman & Polinski, 1978; Hagerman & Staron, 1983; Jackson & Secher, 1976; Mickelson & Hagerman, 1982; Pyke, 1979; Szögy & Cherebetiu, 1974; Vrijens & Bouckaert, 1984; Wright, Bompa & Shephard, 1976), and as a result, most physiological studies have been concerned with measuring the oxygen demands of rowing at submaximal and maximal levels.

Rowing is a continuous performance which utilizes arm, leg and back musculature; therefore, the energy demands placed on oarsmen are great (Jackson & Secher, 1976). Oarsmen, during a 2,000 meter race, do work at intensities which are near to their maximal cardio-respiratory capacity (Vrijens & Bouckaert, 1984). Experiments under laboratory conditions suggest that during a 6 minute, 2,000 meter performance, about 70% of the total energy cost is produced by aerobic processes, while the anaerobic component accounts for the remaining 30% (Hagerman & Lee; 1978). Because of the importance of the aerobic component in rowing performance, the determination of maximal oxygen uptake ($\dot{V}O_2$ max) is undoubtedly a basic criterion when assessing the aerobic power of a rower. In order to increase this aerobic power, an optimal endurance training program is needed.

Maximal oxygen uptake has been used extensively as an objective measurement of physical work capacity, and as an indicator of performance in endurance events for both trained and untrained individuals (Åstrand & Rodahl, 1977; Bergh, Thorstensson, Sjödin, Holten, Piehl & Karlsson, 1978; Cunningham, Goode & Critz, 1975; MacDougal, 1977), however, these values normally serve only to rank athletes or their untrained peers with respect to previously determined norms or expected maximal standards. Although this information is useful in determining the success of various training programs as well as in providing a stimulus for training, it does little to help when designing specific aerobic and anaerobic exercise programs to meet individual or team training needs.

The percentage of $\dot{V}O_2$ max at which an increase in blood lactate occurs is known as the anaerobic threshold (AT) and can be determined non-invasively during a graded exercise test by analysing expired respiratory gases (Davis, Frank, Whipp & Wasserman, 1979). Many studies have indicated that the AT can be increased with training (Davis et al., 1979; Denis, Fougnet, Poty, Geyssant & Lacour, 1982; Dwyer & Bybee, 1983; MacDougall, 1977; Williams, Wyndham, Kok & Von Rahden, 1967; Yoshida, Yoshihiro & Takenchi, 1982).

The non-invasive technique for the measurement of AT (Davis, Vodak, Wilmore, Vodak & Kurtz, 1976; Naimark, Wasserman & McIlroy, 1964; Wasserman & McIlroy, 1964; Wasserman, Whipp, Koyal & Beaver, 1973) was originally designed for use as a diagnostic tool for people suffering from cardiovascular and/or respiratory abnormalities. This technique, however, can also be very useful when applied to asymptomatic subjects and, in particular, to highly conditioned endurance athletes. By measuring the AT of a rower during a step-wise, progressive $\dot{V}O_2$ max test, it is possible to determine an individual's power output (PO), heart rate (HR), and $\dot{V}O_2$ at AT in addition to maximum values for ventilation ($\dot{V}E$),volume of oxygen ($\dot{V}O_2$max), volume of carbon dioxide ($\dot{V}CO_2$max) and HR. The AT information obtained will then allow the outlining of individualized training programs which can limit the deleterious effects of metabolic acidosis. By varying exercise intensity in relation to AT, PO and $\dot{V}O_2$ max, it will be possible to determine the effectiveness of various training programs in increasing a rower's AT, $\dot{V}O_2$ max or both concurrently.

Traditionally, training prescriptions based on specific percentages of $\dot{V}O_2$ max have been used to impose work stress believed to be optimal in terms of the required effort and resulting benefits (American College of Sports Medicine, "Position Statement", 1978; Dwyer & Bybee, 1983 Pollock, 1973). While the AT is not a constant percentage of $\dot{V}O_2$ max for all individuals, its influence on fuel use and on lactate accumulation and its supposed reflection of a discrepancy between oxygen supply and demand suggest that precise training prescriptions, with respect to metabolic stress, may be developed with the AT as the major consideration. Some studies have suggested that the AT, reflecting subtle changes in cellular metabolism, may be a more sensitive indicator of circulatory and metabolic adaptations to exercise than some arbitrary fraction of the $\dot{V}O_2$ max (Wasserman et al., 1973; Weltman, Katch, Sandy & Freedson, 1978). Currently, training prescriptions based on percent $\dot{V}O_2$ max do not distinguish between work above and below AT (Katch & Weltman, 1979). Consequently, exercise performed at a specific intensity with the commonly used range of 50 to 85% $\dot{V}O_2$ max, may result in dissimilar work stresses in individuals with different AT values but similar $\dot{V}O_2$ max (Weltman et al., 1978). A more uniform training stress may be imposed if work is equated on the basis of AT (Davis et al., 1979; Katch & Weltman, 1978; Dwyer & Bybee, 1983; Mickelson & Hagerman, 1982; and Vrijens & Bouckaert, 1984).

The AT, expressed as $\dot{V}O_2$ ($L \cdot min^{-1}$) or percent $\dot{V}O_2$ max, must be translated into a field-measurable term if training intensity is to be regulated at a fixed percent of AT. Heart rate can be an effective means of regulating the intensity of exercise above or below the threshold. The effect of training specificity on AT in rowers has not been directly examined. The amount and intensity of training necessary to produce changes in the AT are not yet known. The coach must determine which form of training will best improve AT.

This study will attempt to reveal information in the area of endurance training and AT as found in rowers. Since this investigator is a national level coach and former rower, there is a personal interest in investigating the effects of off-season training on the aerobic power and anaerobic threshold in male rowers. Implications of this study may improve the knowledge and coaching skills of this researcher.

Delimitations

1. The subjects of this study were seven male rowers, members of the Thunder Bay Rowing Club, who ranged from 15 to 29 years of age.
2. The investigative period was 8 weeks in duration, commencing April 2, 1984, and terminating May 28, 1984.
3. The subjects were required to complete three training sessions, each about 50 to 60 minutes in duration, per week.
4. Training was carried out on rowing ergometers.
5. Diurnal variation was avoided by testing the subject at the same time each day.

Limitations

1. The subjects in this study participated on a voluntary basis.
2. The subjects completed all testing and training sessions during the investigative period.
3. It was assumed that the subjects would exert maximum effort on $\dot{V}O_2$ max tests.
4. It was assumed that the dependent variables ($\dot{V}O_2$ max and AT) would accurately detect any change in the performance of the subjects.
5. Any change in the performance of the subjects was due to the training effect.

Definitions

Aerobic Power (AP) Also called oxygen uptake, and maximal oxygen consumption ($\dot{V}O_2$ max). The greatest amount of oxygen a person is able to utilize during a maximal effort. It can be reported as absolute $\dot{V}O_2$ (liters · min $^{-1}$) or relative $\dot{V}O_2$ max (milliliters · Kilogram body weight^{-1}· min $^{-1}$).

Anaerobic threshold (AT) or Ventilatory Threshold (VT) The point of curvilinear increase of ventilation during graded exercise (Wasserman et al., 1973). Anaerobic threshold is identified by a departure from linearity of the $\dot{V}EO_2$, $\dot{V}E$ and $\dot{V}CO_2$ relative to $\dot{V}O_2$, FEO_2 and $FECO_2$.

Carbon dioxide production ($\dot{V}CO_2$) The volume of carbon dioxide produced per minute by the body.

Continuous endurance training (CET) Exercise performed to completion without rest periods.

The expiratory fraction of carbon dioxide ($FECO_2$) Mixed carbon dioxide present in the expired air sample.

The expiratory fraction of oxygen (FEO_2) Mixed oxygen present in the expired air sample.

Heart Rate (HR) The number of heart beats per minute.

Interval training (IT) Exercise performed with alternate periods of rest, as opposed to continuous training.

Oxygen consumption ($\dot{V}O_2$) The volume of oxygen utilized per minute by the body.

Respiratory exchange ratio (RER) The ratio of the volume of carbon dioxide expired per minute ($\dot{V}CO_2$) to the volume of oxygen consumed during the same time interval ($\dot{V}O_2$). Proportionately more fats are being metabolized when the RER is near 0.7, and more carbohydrates are being metabolized when the RER is near 1.00.

Ventilation ($\dot{V}E$) The volume of air expired per minute.

The ventilatory equivalent of carbon dioxide ($\dot{V}E \cdot VCO_2^{-1}$) The ratio of ventilation to carbon dioxide produced per minute.

The ventilatory equivalent of oxygen ($\dot{V}E \cdot VEO_2^{-1}$) The ratio of ventilation to oxygen consumed per minute.

Chapter 2

REVIEW OF LITERATURE

Maximal Oxygen Uptake in Oarsmen

Maximal oxygen uptake is an excellent indicator of aerobic fitness (Åstrand & Rodahl, 1977). An increase in the total aerobic metabolism during maximal exercise of 4 to 6 minutes duration will be reflected by a similar increase in the $\dot{V}O_2$ max (Secher et al., 1982a). Thus, the use of aerobic power for the assessment of aerobic fitness level seems justified in oarsmen.

Maximal aerobic power measured in young untrained men is about 3.4 $L \cdot min^{-1}$ (Åstrand & Rodahl,1977), while in oarsmen it ranges from between 2.4 $L \cdot min^{-1}$ (Strydom,Wyndham & Greyson, 1967) and 6.6 $L \cdot min^{-1}$ (Hagerman et al., 1978). The highly developed aerobic power of oarsmen is essential in maintaining the high steady state energy during the body of the race and permits the oarsmen to work for at least 5 minutes at 97 to 98% of maximal aerobic power (Hagerman et al., 1975). This supposition is strengthened by the finding of a positive correlation between the average $\dot{V}O_2$ of the crew and their placing in international championships. A direct relationship between placing in an international championship regatta and the average $\dot{V}O_2$ max of a crew has been established ($y = 6.15 - 0.08x$, $r = 0.87$, $n = 10$) (Secher et al., 1982b), giving a value of 6.1 $L \cdot min^{-1}$ for first place and 5.1 $L \cdot min^{-1}$ for 13th place when 15 to 20 crews are competing, as in FISA championships. These findings indicate that the maximal aerobic power of the best oarsmen may be a limiting factor in rowing performance. The mean

$\dot{V}O_2$ max was 6.1 L· min^{-1} for the crew taking first place, 5.7 L· min^{-1} for the crew taking the sixth place, and 5.1 liters · min · $^{-1}$ for the crew attaining the thirteenth place .

One group reported a $\dot{V}O_2$ max of 7.7 L· min^{-1} (Nowacki, Krause & Adam, 1969), however, their $\dot{V}O_2$ increased curvilinearly as work intensity increased. The large $\dot{V}O_2$ max of oarsmen are due mainly to their large body dimensions. When the $\dot{V}O_2$ max is expressed per kilogram of body weight (Vaage & Hermansen, 1977), the smaller oarsmen show similar or slightly larger values.

A correlation between rowing performance and vital capacity (Ishiko, 1967) may reflect the advantage of the larger oarsman. International competitive oarsmen have vital capacities of about 6.8 L (BTPS) with a largest recorded value of 9.1 L, but are characterized by their large aerobic power, and their large body size (Secher, 1983).

Studies on elite rowers have suggested that the $\dot{V}O_2$ max values are indeed important. Szögy and Cherebetiu (1974), stated that rowers have been found to exhibit some of the highest absolute $\dot{V}O_2$ max values of all athletes. Åstrand and Rodahl (1977) also reported that rowers had the highest absolute $\dot{V}O_2$ max values (5.8 to 6.0 L· min^{-1}) next to cross country skiers (6.3 L· min^{-1}) of all the athletes they tested.

Hagerman et al. (1979) has published a physiological profile of many (n=663) elite heavyweight, lightweight and female rowers. The mean value of 6.1 L· min^{-1} is similar to the value reported by Åstrand and Rodahl, 1977; Jackson and Secher, 1976; Secher, 1973; Szögy and Cherebetiu, 1974. It may therefore be postulated that the greater $\dot{V}O_2$ max contributes to a superior rowing performance.

Anaerobic Threshold

During low levels of physical effort, oxygen demand by the working muscle is adequately supplied by adjustments in cardiac output and increased oxygen extraction. With a further increase in work intensity, the increasing contribution of anaerobic metabolism results in production of lactic acid (LA). Anaerobic threshold (AT) has been defined as the rate of work or $\dot{V}O_2$ just below the point at which LA begins to accumulate in the blood. According to Wasserman and McIlroy (1964), evidence of anaerobic metabolism is provided by biochemical changes in the blood. It may be detected as an increase in blood LA concentration to 2 $mMol \cdot L^{-1}$, and as a decrease in blood bicarbonate (HCO_3^-) and hydrogen ion (pH).

Indirect evidence of the onset of anaerobic metabolism is provided by non-linear increases in minute ventilation ($\dot{V}E$), respiratory exchange ratio (RER), carbon dioxide (CO_2) production and an abrupt increase in the fraction of expired oxygen (FEO_2), with progressively increased work rate. Several investigators have established the validity and reliability of AT determination while employing non-invasive measures.

In an early investigation, Naimark, Wasserman and McIlroy (1964) found that increases in blood LA levels were associated with abrupt increases in RER and a decrease in blood (HCO_3^-), and that these changes occured at lower work loads in heart patients than in healthy individuals; however, Wasserman, Whipp, Koyal and Beaver (1973), concluded that the RER was of limited usefulness in determining the AT because the elevation of RER occurred only when the rate of HCO_3^- change was at its maximum.

Wasserman et al. (1973) defined the AT as the work rate at which the volume of CO_2 produced and the VE deviate from linearity as compared to increases in $\dot{V}O_2$ as work load is incremented. Davis, Vodak, Wilmore, Vodak and Kurtz (1976) measured gas exchange parameters and blood LA levels during progressive bicycle ergometer exercise on nine male subjects. Of the respiratory parameters measured, $\dot{V}E$, volume of carbon dioxide produced ($\dot{V}CO_2$) and FEO_2 were found to give estimates of the AT within 30 seconds of each other. No significant difference was found between AT by blood LA or gas exchange parameters. Determination of test- retest correlation coefficients were 0.77, 0.74 and 0.72, respectively.

In a later investigation, Davis et al. (1979) measured exercise responses in nine sedentary middle-aged males and seven control subjects before and after an endurance training program. Each subject was given two work incremented ergometer tests before and after training. The criteria for AT were a systematic increase in the $\dot{V}EO_2$ without an increase in the $\dot{V}ECO_2$ and a systematic decrease in end-tidal oxygen presure (PO_2) without a decrease in end-tidal carbon dioxide pressure (PCO_2). Test-retest correlation coefficients for the AT expressed as $\dot{V}O_2$ in $L \cdot min^{-1}$ for all subjects were 0.94 pre-training and 0.95 post- training.

Bailey, MacNab and Wenger (1977) measured VE and blood LA of 26 males during a continuous incremental bicycle ergometer work test. No difference was found in estimates of the AT by the two methods. It appears that measurement of the AT from gas exchange parameters is a valid procedure (Davis et al., 1976).

It has been suggested that the AT may provide an indication of functional work capacity or fitness. Several investigators (Naimark, et al., 1964; Wasserman et al., 1973) have reported findings that suggest that the AT of patients with limited cardiovascular function is well below that of healthy individuals. The patients had significantly greater changes in RER and higher LA levels than the healthy subjects at similar work rates, leading to the conclusion that the AT appears to accurately reflect the functional capacity of these groups.

Other evidence suggests that the AT may be useful in assessing physical work capacity in athletes. Weltman and Katch (1979) found that trained athletes reached AT at greater absolute and relative levels of $\dot{V}O_2$ than untrained individuals. A number of investigators have examined differences in the AT in trained and untrained subjects using a cross-sectional approach with the "break-away" ventilatory responses during progressive exercise as the indicator that the AT has been reached. McDougal (1977) compared nine elite athletes with ten non-athletes. The AT occurred at 85% and 70% of $\dot{V}O_2$ max, respectively. Patton, Heffner, Baun, Gettman and Raven (1979) reported similar findings using the non-linear inflection point in the ventilatory responses to determine the AT during progressive treadmill exercise. The AT occurred at a significantly higher percentage of $\dot{V}O_2$ max in varsity cross-country runners (N=5) than physically fit non-runners (N=6), or at 75% and 53% percent of $\dot{V}O_2$ max, respectively.

Londeree and Ames (1975) evaluated maximal steady state in 13 adult males during mild to exhaustive discontinuous treadmill exercise. Venous blood LA was measured during minutes 10 and 15 of exercise. Subjects were classified as low-fit, medium-fit and high-fit from an activity recall record for the previous six month. Significant differences between submaximal HR at 2.2 $mMol \cdot L^{-1}$ LA were found between all three groups. The work rate corresponded to 74%, 60% and 47% of $\dot{V}O_2$ max for the high, medium and low-fit groups, respectively. Relative $\dot{V}O_2$max differences were significant for the high and low-fit groups. It is concluded from these results that the rate of work above which there is a significant accumulation of LA in the blood (above 2 $mMol \cdot L^{-1}$) is reached at a higher percentage of the $\dot{V}O_2$ max in high-fit than in low-fit subjects.

In a related study, Weltman, Katch, Sandy and Freedson (1978) compared submaximal exercise responses in 22 female subjects matched with respect to $\dot{V}O_2$ max. Subjects were subsequently classified with respect to $\dot{V}O_2$ at the onset of metabolic acidosis, determined using gas exchange variables, into high and low $\dot{V}O_2$-AT groups. The high $\dot{V}O_2$-AT group reached a steady state for $\dot{V}O_2$ at a significantly faster rate than the low $\dot{V}O_2$-AT group. In addition, the AT was reached at a significantly higher percentage of $\dot{V}O_2$ max in the high-fit group. The percentages were 53% and 46% for the high and low-fit groups, respectively.

Comparing 12 trained male cyclists with 12 untrained males during submaximal bicycle ergometer exercise, Edwards, Jones, Oppenheimer, Hughes and Knill-Jones (1979) found steady state HRs were reached in less than one minute in trained subjects, whereas steady state HRs were generally not attained until two minutes in the untrained group. Blood LA increased at a higher $\dot{V}O_2$ in the trained than the untrained group, and at a higher percentage of $\dot{V}O_2$ max.

In summary, the AT occurs at higher absolute levels of $\dot{V}O_2$ at a higher percentage of the $\dot{V}O_2$ max in healthy individuals than in patients with cardiovascular disease, and in endurance-trained individuals than in untrained individuals. In addition, trained individuals reach steady state $\dot{V}O_2$ faster and are able to work with only minimal levels of blood LA at higher $\dot{V}O_2$ levels than untrained individuals. Furthermore, LA production occurs at lower work levels in the untrained. These findings suggest that the AT may be a useful submaximal criterion of physical condition.

Further insight into the relationship between the AT and training has been provided by several longitudinal studies. Davies et al. (1979) compared the physiological responses of nine middle-aged men before and after 9 weeks of endurance training on the bicycle ergometer with those of seven control subjects. The subjects trained at a $\dot{V}O_2$ of 50% between the AT and $\dot{V}O_2$ max for the first four weeks. This was increased to 70% for the last five weeks. Following training, AT increased 44% when expressed as an absolute rate of $\dot{V}O_2$ $L \cdot min^{-1}$ and 15% when expressed as a percentage of $\dot{V}O_2$ max. No changes were observed in the control subjects. Williams, Wyndham, Kok and Von Rahden (1967) reported increases in the AT using a criterion of excess LA, when expressed both as an absolute rate of work and relative to $\dot{V}O_2$ max, in 13 males following 4 to 16 weeks of training four hours daily at submaximal and maximal levels of work. The level of work at which excess LA appeared in the blood increased from 46% to 62% of $\dot{V}O_2$ max.

McLellan and Skinner (1981) reported conflicting findings in 14 male subjects training on the bicycle ergometer 30 to 45 minutes per day, 3 times per week for 8 weeks. They reported increases in the AT on an absolute basis, but no change was observed when AT was expressed relative to $\dot{V}O_2$ max. In addition, subjects training 5% to 15% above the AT did not differ from those training at or below the AT.

Mickleson and Hagerman (1982) tested 25 members of the 1980 U.S. Olympic Rowing Team during a progressive (to exhaustion) rowing ergometer exercise. Anaerobic threshold, $\dot{V}O_2$ max, HR and POs were also measured to gauge the severity of the exercise and were compared with metabolic data. Power increments of 27 watts each minute were achieved by progressively increasing the brake weight resistance on the ergometer while maintaining a stroke rate of 28 to 32 strokes $\cdot$ min $^{-1}$ and spinning the ergometer flywheel at 550 revolutions $\cdot$ min $^{-1}$. Anaerobic threshold measurements were determined by observing the onset of a non-linear relationship between $\dot{V}O_2$, $\dot{V}E$ and $\dot{V}CO_2$. A mean AT of 83% of $\dot{V}O_2$ max, and a mean HR value at AT of 167 beats $\cdot$ min^{-1} were found.

Dwyer and Bybee (1983) examined the HR response and percent maximal HR (%HRmax) at the AT in 20 young women. The AT, $\dot{V}O_2$ max and HR were assessed during incremental (25 watts each minute to exhaustion). Ventilation and gas exchange were measured each minute. Anaerobic threshold was identified by departure from linearity of the $\dot{V}EO_2$, $\dot{V}E$, and

$\dot{V}CO_2$ relative to $\dot{V}O_2$. Reliability coefficients for AT and HR at AT were 0.92 and 0.86, respectively. The mean AT observed in the incremental tests carried out to exhaustion was 70.1% of $\dot{V}O_2$ max, ranging from 54 to 83%. The mean work rate at AT was 151$\pm$ 28 Watts or 73% of the average maximal work rate. They concluded that training prescriptions for intensity can be developed and expressed in percent HR max at AT as the major consideration. Indeed, evidence is accumulating which suggests that the training prescriptions lack metabolic specificity if they are not based on AT.

Based on the research reviewed above, it appears that increases in the AT may be observed following training (when the AT is expressed in an absolute rate of work). Increases in the AT expressed relative to $\dot{V}O_2$ max may depend on the initial level of condition of the subject and the type of training program engaged in, particularly with respect to the intensity of exercise performed.

The Relationship Between the Ventilatory and Blood Lactate Responses

As the intensity of exercise increases from low levels to approximately 40% to 50% of $\dot{V}O_2$ max, a greater portion of oxygen is extracted by the active tissues, resulting in a decreased fraction of oxygen in the expired air (FEO_2). In addition, there is a proportional increase in CO_2 produced oxidatively and in expired $FECO_2$. Ventilation rises in proportion to the progressively in- creasing $\dot{V}O_2$ and $\dot{V}CO_2$ expired $\dot{V}ECO_2$. Although the entry rate of LA into the blood may be increased during these levels of exercise, the removal rate of LA is also increased (Graham, 1978; Sutton & Jones, 1979). As a result, little or no change in blood LA is usually observed. Further, the RERs of 0.7 to 0.8 suggest that the predominant source of energy at this intensity of exercise involves FFA oxidation (Skinner & McLellan, 1980).

As the exercise intensity continues to increase and reaches a level exceeding approximately 50% $\dot{V}O_2$ max, there is an initial continuous rise in LA from values close to 1.5 to 2.0 $mMol{\cdot}L^{-1}$. This change in acidity (H^+) is buffered principally by the base bound as HCO_3^- (Bouhuys, Pool, Binkhorst & Van Leeuwen, 1966), resulting in an increased production of CO_2 from the dissociation of carbonic acid (H_2CO_3) and a continuous rise in $FECO_2$ (Skinner & McLellan, 1980). This increased CO_2 production which results in a disproportionate rise in $\dot{V}E$, however, is related to the change in $\dot{V}CO_2$, as arterial CO_2 levels remain normal (Sutton & Jones, 1979; Wasserman, Whipp & Davis, 1981). This results in a lower extraction of oxygen relative to the total ventilation and a subsequent rise in FEO_2 (Wasserman et al., 1973). The point at which these changes in gas exchange variables and/or LA occur have been defined as the AT (Wasserman et al., 1973), the lactate threshold (Ivy, Whithers, VanHandel, Elger & Costill, 1980), and the aerobic threshold (AerT) (Kindermann, Simon & Keul, 1979; Skinner & McLellan, 1980).

With increasing intensity of exercise between approximately 50% to 80% $\dot{V}O_2$ max, LA continues to increase to values close to 4 $mMol{\cdot}L^{-1}$ (Sjödin & Jackobs, 1981; Galdwell & Pekkarinen, 1983; Davis, Gass, Eager & Basset, 1981). The proportionate changes in $\dot{V}E$ and $\dot{V}CO_2$ maintain normal arterial PCO_2 during this period of isocapnic buffering, suggesting that respiratory compensation is effective (Skinner & McLellan, 1980).

After approximately 80% $\dot{V}O_2$ max and with increasing intensity, LA increases rapidly, resulting in a greater change in arterial pH. This decreased pH increases the afferent discharge from the carotid bodies to the respiratory centre, which increases $\dot{V}E$ at a rate greater than the continued rise in $\dot{V}CO_2$ (Davis, Basset, Hughes & Gass, 1983). As a result, $FECO_2$ begins to decrease, while FEO_2 continues to rise (Skinner & McLellan,1980). This intensity is associated with a point of "break-away" ventilation and/or the onset of a rapid rise in LA and has been associated with the terms respiratory compensation (Wasserman et al., 1973, and 1981), onset of blood lactate accumulation or OBLA (Jacobs, 1983; Sjödin & Jacobs, 1981) and the AT (Kinderman et al., 1979; Skinner & McLellan, 1980).

As noted, considerable variability exists in the literature with respect to the terminology used to identify these changes in the ventilatory and blood LA responses during an incremental test. This controversy over terminology appears to be related to two principal issues: the changes in ventilation and gas exchange resulting from and/or relating to the alterations in blood LA values, and the criteria used to define anaerobiosis and its relationship to tissue hypoxia.

The mechanisms involved in the control of ventilation during exercise have provided researchers with a complex topic of investigation for many years. Review articles have summarized the current foci of investigation of the ventilatory response to exercise as relative to the influence of neural and hormonal stimuli originating in the exercising muscle (Mahler, 1979) and as carotid body chemoreceptor sensitivity (Whipp,1971). Swansson (1979) characterized the control of ventilation in terms of feed-forward and feedback regulating mechanisms. It would appear that neural impulses originating in the exercising muscles, CO_2 flux to the lungs, increased venous return and/or direct cortical influence, may provide the feed-forward stimuli for regulating ventilation relative to the metabolic state of active tissue (Wasserman et al., 1973 and 1981). Feedback control appears to involve the regulation of arterial CO_2 (and pH) by the carotid bodies and the "fine tuning" by higher cortical centers (Whipp, 1971).

Since the buffering of elevated CO_2 in the blood by HCO_3^- represents an additional non-metabolic CO_2 stimulus to increase ventilation, Wasserman et al. (1973) examined the relationships among responses in LA, HCO_3^-, VO_2 and $\dot{V}E$ during an incremental (to exhaustion) work test. It was found that the initial continuous increase in LA and decrease in HCO_3^- occurred at the same PO level as the first disproportionate increase in $\dot{V}CO_2$ and $\dot{V}E$, i.e., at AT. These findings suggest a "cause and effect" relationship between the increasing blood LA and $\dot{V}E$ response. Subsequent studies by Davis et al., (1976) and by Yoshida, Yoshihiro and Takeuchi (1981) produced correlation coefficients of 0.95 and 0.86, respectively, between LA response and the PO associated with the initial change in $\dot{V}E$.

Sutton and Jones (1979) have stated, however, that increasing LA values will effect the exercise ventilatory response in two ways: as an increased CO_2 flux to the lungs due to the buffering of LA by HCO_3^- and as a change in pH, the magnitude of which depends on the relative changes in

HCO_3^- and the partial pressure of CO_2. Therefore, with rapidly increasing blood LA values, one would expect not only an augmented CO_2 flux but also a substantial increase in H^+ concentration due to decreasing HCO_3^- levels.

During low-intensity exercise, increasing amounts of FFA are released into the circulatory system and transported to the working muscle. Since the rate of diffusion of FFA across the cell membrane is proportional to its concentration gradient, high levels of FFA in the blood ensure a constant supply, making FFA the dominant source of fuel for a contracting muscle at low PO levels (Issekutz, Shaw & Issekutz, 1976).

As the exercise intensity increases, more ST and possibly some FT fibres will be recruited (Burke,1980; Éssen, 1978a & b); this produces a greater need for, and utilization of, ATP, with a corresponding increase in the concentration of adenosine diphosphate (ADP), adenosine monophosphate (AMP) and phosphate (P_i). Since FFA oxidation, however, would still represent a predominant substrate for oxidative phosphorylation, some inhibition of pyruvate oxidation will occur. As a result, there is an imbalance between the rate of pyruvate production, regulated by the energy state of the tissue, and pyruvate oxidation, regulated by the proportion of FFA utilized as a substrate for oxidative metabolism (Issekutz et al.,1976). The intensity of exercise associated with this imbalance between a glycolytic and oxidative substrate flux should also be associated with an initial continuous rise in blood LA values and the initial disproportionate increase in $\dot{V}E$ or AerT (Skinner & McLellan, 1980).

The previous discussion has defined AT as an intensity of exercise that is associated with the initiation of a hyperventilatory response that is greater than the response observed at POs slightly above AerT. The relationship of $\dot{V}E$ to $\dot{V}CO_2$ from low-intensity to maximal exercise can be characterized by three different linear equations: below AerT, above AerT but below AT and above AT (Skinner & McLellan, 1980).

As noted previously, the term "anaerobic threshold" (AT) has been used to define the change in $\dot{V}E$ associated with a rise in blood LA (Wasserman et al., 1973) and the point of "break away" $\dot{V}E$ associated with the onset of a rapid rise in blood LA (Kindermann et al., 1979; McLellan & Skinner, 1980). This controversy appears to be related to the onset of anaerobiosis. Research by Graham (1978) demonstrated that LA was produced when there was an insufficient supply of O_2 to the working muscle. Based on these findings, it was then generally assumed that the presence of LA implied hypoxia. This assumption, however, has been questioned by a number of investigators (Holloszy, 1976).

It has been shown that athletes can work at high intensities for prolonged periods with low levels of LA (Costill, 1970). Following the assumption that LA implies hypoxia, the lower LA at a higher relative PO would be due to a removal of hypoxic conditions (Holloszy, 1976). If these hypoxic conditions were reduced, then $\dot{V}O_2$ at a given submaximal PO would have to increase, suggesting an alteration in total body efficiency with training. Since $\dot{V}O_2$ at a given submaximal PO does not change with training, however, local hypoxia cannot be the reason for change in LA (Holloszy, 1976).

It should be realized that blood LA values are also influenced by muscle fibre composition and muscle fibre recruitment (Sjödin,1976). For example, the production and removal of LA are influenced by the content of lactate dehydrogenase (LDH) in the sarcoplasm of muscle (M) specific subunits (Sjödin, Thorstenson, Firth, & Karlsson,1976). Therefore, as pyruvate concentrations increase within the sarcoplasm, less LA will be produced with the heart (H)-LDH isozyme. Consequently, it is generally assumed that M-LDH facilitates the reduction of pyruvate to LA, whereas H-LDH favours the oxidation of LA to pyruvate for subsequent utilization in the Krebs cycle (Sjödin et al., 1976).

There appears to be a relationship between muscle fibre composition and both the total LDH activity and LDH isozyme distribution. Slow twitch muscle fibres have a relative H-LDH activity (Sjödin et al., 1976), while FT fibres have almost three times as much M-LDH activity (Sjödin et al.,1976). Graham (1978) hypothesized that FT fibres would also be more likely to become hypoxic because they have lower values for capillary-fibre ratio, mitochondrial concentration and a lower rate of oxidative metabolism. This is in agreement with the finding that LA concentration is higher in FT fibres following intense dynamic exercise (Tesch, Sjödin & Karlson, 1978).
Similarly, Bonen, Campbell, Kirby and Belcastro (1978) found a moderate but significant relationship (r=0.54) between ST fibres and the rate of LA removal after heavy exercise. They suggested that FT fibres tend to produce LA, while ST fibres continuously extract and oxidize LA from the blood and from FT fibres. In addition, Graham (1978) found an inverse relationship between the percentage of ST fibres and the LA concentration gradient

between muscle and blood. Although the blood LA concentrations were similar, the muscle LA concentration in FT fibres was three times as high as that found in ST fibres. The explanation for this was that FT fibres have a greater rate of LA production and/or a lower rate of LA release.

During the various phases of progressive exercise, there appears to be a preferential recruitment of specific fibre types (Burke, 1980). Based on studies of glycogen depletion in muscle fibres, (Éssen, 1978a & b) found a greater loss of glycogen in ST fibres at intensities of 30 to 85% $\dot{V}O_2$ max. As the duration or intensity of work increased, more FT fibres were recruited. Éssen (1978a) also found that FT oxidative fibres were recruited before FT glycolytic fibres. Athough patterns of glycogen depletion do yield information about muscle fibre recruitment, they are not necessarily indicative of the extent to which the different fibres have been active, since muscle glycogen is not the only substrate used to produce energy (i.e., fat and glucose can also be used).

Summarizing these findings, it would appear that the initial alterations in the ventilatory and blood LA response are associated with tissue hypoxia, and that the term AT is adequate to represent these changes. The onset of the rapid rise in blood LA and the point of break-away $\dot{V}E$ appear to be related more to anaerobiosis and tissue hypoxia due to the recruitment of the more glycolytic FT fibres, with their predisposition for hypoxia, and a possible reduction of the mitochondrial oxidative potential.

Factors Influencing the Determination of Anaerobic Threshold

During a progressive work test, AT has usually been determined by using non-invasive measurement techniques, e.g., a non-linear increase in $\dot{V}E$ and $\dot{V}CO_2$, an increase in end-tidal O_2 tension without a corresponding decrease in end-tidal CO_2 tension, and an increase in RER (Wasserman et al., 1973). Davis et al. (1976) found a reliability coefficient of 0.95 between the AT determined from these gas exchange variables and AT determined from repeated serial venous LA samples. They also reported a test-retest correlation coefficient of 0.72 for AT determinations from gas exchange alterations. Subsequently, Davis et al. (1979) reported a test-retest reliability coefficient of 0.95 for AT determined from an increase in the ventilatory equivalent for O_2 ($\dot{V}E \cdot \dot{V}O_2^{-1}$) without an increase in the ventilatory equivalent for CO_2 ($\dot{V}E \cdot \dot{V}CO_2^{-1}$). Although the use of only one or two criteria measures may provide a more reliable non-invasive estimate of AT, the sensitivity of a ratio measure (such as $\dot{V}E \cdot \dot{V}O_2^{-1}$) has been questioned. For example, Davis et al. (1979) suggested that differences occurring in the absolute change of two measures (e.g., $\dot{V}E$ and $\dot{V}O_2$) are not necessarily reflected by the same change in the ratio of these variables (e.g., $\dot{V}E \cdot \dot{V}O_2^{-1}$). It is possible, therefore, that a greater change in $\dot{V}E$ is required to detect a change in the $\dot{V}E \cdot \dot{V}O_2^{-1}$ as an estimate of AT, if the ventilatory response alone was examined relative to the changing $\dot{V}O_2$.

Anaerobic threshold determinations have generally been based on direct LA measures (Kindermann et al., 1979; Stegmann et al., 1981). Although mean LA concentrations at AT approximate 4 $mMol \cdot L^{-1}$, Stegmann et al. (1981), have emphasized the need for the evaluation of AT based on individual blood LA kinetics. Individual differences associated with diet (Ivy et al., 1980), alterations in the time course between muscle LA production and release (Graham, 1978), intracellular and extracellular buffering capacity (Stamford et al., 1981), the dissociation of pH and LA ion muscle efflux rates (Jones, 1980), as well as LDH isozyme patterns (Sjödin, 1976) may all influence blood LA values. Therefore, the assignment of absolute or arbitrary levels (as used by Sjödin & Jacobs, 1981) is of little value as a criterion of equal metabolic stress among all individuals (Åstrand, 1984).

Wasserman et al. (1973) and Stamford, Weltman, Moffat and Sandy (1978) suggested that POs of at least 2 to 3 minutes duration were necessary for the accurate determination of AT. Due to the delay in diffusion of LA from muscle to blood, shorter PO durations are likely to result in overestimates, that is, the subject will be exercising at a higher intensity of and will have a higher $\dot{V}O_2$ before the blood LA rises due to conditions produced during the previous PO.

Davis et al. (1976) measured LA and various gas exchange variables during arm cranking, as well as, during leg exercise on a cycle ergometer and treadmill. There were no individual differences between leg cycling and treadmill walking when the respective AT values were expressed relative to the $\dot{V}O_2$ max (% $\dot{V}O_2$ max) obtained with the same exercise test. Significatly lower values for $\dot{V}O_2$ max and relative AT were found for arm cranking. The authors speculated that these lower values were due to the smaller muscle mass of the arms, to little or no experience with arm cranking so that the arms were less trained, to differences in ST and FT muscle fibre distribution between arms and legs, or to a lack of uniform motor unit recruitment in arm work. Likewise, Stamford et al. (1978) hypothesized that nonfamiliarity could have produced different patterns of motor fibre recruitment. On the other hand, they did not feel that the size of the total muscle mass involved was important since no difference in relative AT values were found during cycling with one or two legs. Withers, Sherman, Miller and Costill (1981) have reported that there is a specificity for relative AT values depending on the mode of testing.

There is little information in the literature on the influence of the type of exercise on AT. Kindermann et al. (1979) have reported, however, that well-trained cross-country skiers were able to exercise at a given intensity for a longer period of time during roller-ski training than during treadmill running. This difference was attributed to the greater muscle mass involved (arms and legs), to the possibility of training specificity since the skiers trained both arms and legs.

Substrate availability also appears to influence the AT. For example, when high levels of blood glucose were present, Ivy et al. (1980) found AT values similar to those found under control conditions. When they elevated blood FFA levels, however, there was a significant rise in relative AT and a reduction in blood LA at AT. Since FFA oxidation inhibits glycolysis (Issekutz et al., 1976), an artificial increase in blood FFA concentrations should produce a greater muscle to blood concentration gradient and a greater inhibition of carbohydrate metabolism at the same PO. As a result, blood LA values should be reduced and AT could occur at a higher PO.

Muscle fibre composition, LDH isozyme patterns and endurance training may effect AT determinations. Ivy et al. (1980) reported that AT was related both to the relative distribution of ST fibres and to oxidative potential of muscle. Therefore, the high relative AT values reported for well-trained endurance athletes (Costill, 1970; Withers et al., 1981) may result both from a high percentage of ST fibres (Bergh, Thorstensson, Sjödin, Holten, Piehl & Karlsson, 1978; Costill et al. 1976a and b; Golnick et al., 1972; Saltin et al.,1977) and from a greater muscle oxidative potential, as reflected by high succinate dehydrogenase (SDH) activity (Costill, Daniels, Evans, Fink, Krahenbuhl & Saltin, 1976a and b; Gollnick et al., 1972; Saltin et al., 1977).

Endurance training may also influence the LDH isozyme pattern of the muscle fibres. For example, Sjödin et al. (1976) found a decrease in total LDH activity with training, as well as, a shift towards the H-LDH isozyme, while, the relative activity of the H-LDH isozyme increased in both ST and FT fibres. A preferential H-LDH isozyme pattern may result in a slower LA production (Sjödin et al., 1976), suggesting that AT could occur at higher relative intensity in trained athletes than in untrained persons. A possible explanation for the fact that endurance athletes may have higher values for AT is that these athletes generally have a lower ventilatory response to similar levels of alveolar CO_2 pressure (Stegmann et al., 1981). Since many determinations of AT are based on alterations in $\dot{V}E$ and $\dot{V}CO_2$, this reduced sensitivity of the peripheral and central chemoreceptors to CO_2 might decrease the magnitude of these changes (Stegmann et al., 1981).

The amount and intensity of training necessary to produce changes in AT are not known. Williams et al. (1976) reported a 16% increase in AT following 4 to 16 weeks of daily training sessions lasting up to 4 hours. This increase was greater than and independent of the mean rise in $\dot{V}O_2$ max of 7%. Similarly, Davis et al. (1979) reported that relative AT values increased from 49% to 57% $\dot{V}O_2$ max following a 9-week exercise program consisting of four 45-minute sessions per week at an intensity of 75-85% $\dot{V}O_2$max. In contrast, McLellan and Skinner (1981), found no change in relative AT after 8 weeks of endurance training, 3 times per week with 30 to 45 minutes of each session at about 60 to 65% $\dot{V}O_2$ max.

In summary, it is apparent that several factors may influence relative AT values. For example, reliable and sensitive non-invasive estimates should be provided by examining the change in the ventilatory response to the progressively increasing $\dot{V}O_2$ with POs of approximately 2 to 3 minutes duration. The pattern of change in the LA response appears to be more useful than assigning absolute LA values to represent each AT. Further, the mode of testing should be specific to allow for a valid cross-sectional or longitudinal comparison of the effects of training on relative AT values.

Effects of Selected Training Protocols

Interval Training

After the development of non-invasive techniques to determine AT, several studies have investigated specific training methods and their effects on the AT. The most commonly investigated training technique is interval training.

Rivera, Metz and Robertson (1980) measured $\dot{V}O_2$ max, maximal LA capacity and performance of athletes during 100-meter and 400-meter timed swims. Twenty-four swimmers, 12 to 19 years of age, were tested before and after 6 weeks of high intensity interval training. The subjects were randomly assigned to one of two training groups. One group trained at 85% of its best performance time and a second group at their AT. Both groups had significant gains in $\dot{V}O_2$, and maximal LA capacity. Both groups improved performance levels, with the AT training group improving at a faster rate. These data support the theory that AT training enhances the efficiency of aerobic and anaerobic metabolic systems and that AT is influenced by swim training. The results of this study indicate that high intensity training has a profound effect on metabolic responses; however, training at AT was equally or more effective with regards to performance.

In another study, Cunningham & Faulkner (1969) investigated aerobic and anaerobic metabolism during a short exhaustive treadmill run. Eight males served as subjects for the 6 week training program. The training program consisted of interval sprints of 220 yards and distance runs of two miles. The short exhaustive runs were performed on a treadmill at a speed of 8 miles per hour at a grade of 20%. Run times ranged from 36 to 66 seconds. The training program resulted in a 23% increase in run time for the short exhaustive run, a 9% increase in oxygen debt, and a 17% increase in blood LA concentration. The authors hypothesized that these parameters indicated an increase in the amount of adenosine triphosphate (ATP) produced by oxidative phosphorylation, by glycolysis and from creatine phosphate (CP) during the short exhaustive run.

Endurance Training

Still other investigators have examined the effects of endurance training on AT. Kinderman et al. (1979) determined AT as identified by 4 $mMol \cdot L^{-1}$ of LA; and measured $\dot{V}O_2$ max in seven cross-country skiers of national skill level. All subjects ran on a treadmill for at least 30 minutes at constant running speeds while maintaining constant HRs. During the exercise, performed with a constant speed, LA concentration initially rose to values of nearly 4 $mMol \cdot L^{-1}$ and then remained essentially constant during the remainder of the exercise. This research was done to show that workload intensities above the AT can be maintained, with slightly elevated LA levels, for prolonged periods of time. The results of this investigation demonstrated that endurance training done with an intensity leading to LA levels in the range of 4 $mMol \cdot L^{-1}$ can be maintained for 45 to 60 minutes or even longer. The study also led to the conclusion that endurance training will maintain a particular level of conditioning when performed in the range of the AT and that it will increase exercise capacity when performed in the range of Aer-AT. Davis et al. (1979) attemped to evaluate the relative alterations in AT and $\dot{V}O_2$ max after 9 weeks of endurance training in healthy middle-aged males. The training program consisted of exercise on a stationary cycle ergometer five days per week for 45 minutes per exercise session. For the first four weeks of training, the subjects exercised at a target HR designed to correspond to a $\dot{V}O_2$ of 50% of the difference between their AT, $\dot{V}O_2$ and $\dot{V}O_2$ max. For the last five weeks of training, this value was increased to 70% of the difference between their AT, $\dot{V}O_2$, and $\dot{V}O_2$ max. The major finding of this study was that AT level, expressed as an absolute $\dot{V}O_2$ and as a fraction of $\dot{V}O_2$ max, increased significantly after endurance training. This study demonstrated that AT is profoundly influenced by endurance training in middle-aged males.

Robinson and Sucec (1980) investigated the effect of training intensity of $\dot{V}O_2$ max, AT, and endurance performance as measured by a 15-minute run. The subjects were 21 healthy active males, with a mean age of 22.3 years, who were divided into three groups and tested prior to and following a twelve-week training program. One group trained by running continuously for 30 minutes at 85% of their $\dot{V}O_2$ max. Another group trained by running intervals at a work to rest ratio of 1 to 3 for 30 minutes; a third group served as a control group with average activity patterns. The data indicated that both moderate and intensive training programs increased AT as well as endurance performance. The data also demonstrated that AT changes are more closely related to endurance performance changes than $\dot{V}O_2$ max changes.

Summary

Quantities of LA form when muscles are activated by anaerobic metabolism processes. Formation of this LA during exercise permits oxidation to proceed anaerobically and accounts for most of the oxygen debt which accumulates during strenuous exercise. Therefore, measurement of blood LA level has traditionally been used as an indicator of anaerobic metabolism. Because the measurement of LA levels in the past required invasive techniques (specifically, blood sampling), precise research concerning AT has been limited. The development of noninvasive techniques, specifically measurement of respiratory gas exchange ratios, has immensely simplified the re-research procedures in this area.

Researchers have investigated the effects of various types of exercise on AT. Their findings have indicated that AT will significantly improve using an interval training (IT) exercise mode. Still other researchers have investigated the effects of endurance training on AT. Their conclusions have been that endurance training will either maintain present AT or, in some cases, increase AT.

There is a need for specific research as to the efficiency of various training intensity levels and the effects that these intensity levels have on AT. There is also a need for investigations involving rowers as subjects since most of the studies have involved other athlete groups.

Chapter 3

METHODS AND PROCEDURES

Research Design

An individual case study approach was employed to investigate the effect of an 8 week endurance training period on the aerobic power and the anaerobic threshold of male rowers.

The Subjects

The subjects in this study were 7 male volunteers ranging in age from 15 to 29 years, all members of the Thunder Bay Rowing Club. The calibre of the subjects is such that they have competed at both provincial and national championships (see Table 1).

Investigative Period

The investigative period for this study was 8 weeks, commencing on April 2, 1984 and terminating May 28, 1984.

Training Schedule

The investigative period consisted of three training sessions per week, each session lasting 50 to 60 minutes. The training was carried out on rowing ergometers (Concept II).

Table 1

Characteristics of Subjects

Subject	Calibre	Age (Yr)	Height (cm)	Weight (Kg)
1. B.B.	National	29	177.0	75.0
2. G.F.	Provincial	15	177.0	78.0
3. T.H.	National	27	178.0	77.0
4. D.J.	Provincial	16	180.0	64.0
5. J.O.	Provincial	18	174.0	76.0
6. J.W.	Provincial	15	192.0	90.5
7. S.W.	National	23	187.0	88.0

Training Programs

The training programs were designed for each individual subject. Decisions regarding training intensity were made based on each subject's AT, $\dot{V}O_2$max, workload and HR, which have been obtained during the pre-training investigative period. The level of intensity of continuous endurance training (CET) was a percentage below the subject's AT and the level of intensity of interval training (IT) was a percentage above the subject's AT (see Table 2). The intensity of training was monitored through the subject's HR (see Appendix B).

Table 2

The intensity, Frequency and Duration of the Eight-Week Continuous and Interval Rowing Ergometer Training Program.

	Training Mode	
	Continuous Training	Interval Training
Intensity	AT-10% $\dot{V}O_2$ max	Low: AT + 10% $\dot{V}O_2$ max
		High: AT+ 15 to 25% $\dot{V}O_2$ max
Frequency	3 · week $^{-1}$	
Duration	50 to 60 Minutes · session $^{-1}$	

Testing Schedule

Each of the subjects visited the Human Performance Laboratory at Lakehead University, on three separate occasions: Orientation session, pre-training test and post-training test. The subjects were tested at the same time and day of the week to avoid diurnal effects. During the orientation session, the subjects were familiarized with the testing environment, equipment and procedures.

Pre- and Post-Training Test Procedures

During the pre- and post-training test, the subjects reported to the laboratory in a post-absorptive state for the performance of an incremental rowing ergometer work test, carried out until the subject reached a state of exhaustion. The subjects were instructed to avoid any vigorous activity 36 hours prior to the testing day. Upon arrival at the laboratory, each subject had his age, weight and height recorded. A balance scale (Continental Scale, Bridgeview, Illinois) was used to measure the subject's weight to the nearest one-tenth of a kilogram and height to the nearest .5 centimeter.

Measuring $\dot{V}O_2$ max

To determine each subject's $\dot{V}O_2$ max, a Gjessing rowing ergometer was used, increasing the subject's workload progressively until he reached the point of exhaustion. The subject began to row at a stroke rate of 27 to 32 strokes per minute, while maintaining the ergometer's flywheel at 600 revolutions per minute. The initial workload was 1.5 Kp and it was increased by .25 Kp every two minutes until a workload of 3.0 Kp was attained. After this point, the workload was increased by .50 Kp to a maximum of 3.75 Kp, whereupon the subject was encouraged to increase maximally the stroke rate and the revolutions per minute until $\dot{V}O_2$ max criteria were observed.

Gas Analysis

Expired air samples were collected continuously and analyzed every 15 seconds, using a pre-calibrated, computerized Beckman Metabolic Measurement Cart (MMC Horizon II system). Along with the continuous presentation of time, $\dot{V}O_2$, $\dot{V}E$, RER and HR were displayed every 15 seconds on the system's visual readout screen. As well, the values for $\dot{V}E$, $\dot{V}EO_2$, $\dot{V}ECO_2$, $\dot{V}O_2$, $\dot{V}O_2 \cdot Kg \cdot min^{-1}$, FEO_2, $FECO_2$, HR, workoad and time were printed every 15 seconds until the test was completed.

Criteria for Attaining $\dot{V}O_2$ max

1. As the workload increases the subject's $\dot{V}O_2$ reaches a plateau or begins to decrease.
2. The RER value should be greater than 1.10.
3. The observed HR should be close to the subject's personal maximum or to the anticipated age maximum.
4. The subject becomes volitionally exhausted.

Heart Rate

Heart rate was monitored continuously with a 3-lead (Campbridge, VS4 model) electrocardiograph, integrated via digital analog to the Beckman MMC system.

Power Output

A mechanical counter as well as an electronic, computerized counter, connected to the ergometer's flywheel registered and recorded the number of revolutions of the flywheel. A television monitor connected to the electronic counter, provided visual feedback to the subject by displaying the number of revolutions recorded after each 30-second interval, as well as after each one-minute interval. This was done in order to control the subject's power output. Upon completion of the test each subject's results (number of revolutions after all 30-second and one-minute intervals, as well as the number of revolutions accumulated during the entire test) was printed out by the computer.

Stroke Rate

The stroke rate was monitored every 30 seconds via a specialized (Herwins, Swiss) rowing stroke rate stopwatch. Each minute, feedback was given to the subject in order to control his stroke rate during the test.

Determination of the Anaerobic Threshold

The ventilatory equivalent for O_2 ($\dot{V}E \cdot \dot{V}O_2^{-1}$), CO_2 ($\dot{V}E \cdot \dot{V}CO_2^{-1}$), as well as $\dot{V}E$, $\dot{V}O_2$, $\dot{V}CO_2$, FEO_2, $FECO_2$ and workload, were plotted against time (in 30-second intervals) until $\dot{V}O_2$ max was reached. Two criteria were used to locate each subject's AT: an increase in the $\dot{V}E \cdot \dot{V}O_2^{-1}$ without an increase in $\dot{V}E \cdot \dot{V}CO_2^{-1}$ and an increase in FEO_2 without a decrease in $FECO_2$. These are identical criteria to those recommended by Davis et al. (1979) who's findings reported a correlation coefficient of 0.95. In this study, test-retest reliability of seven AT rowing tests, determined by averaging the analyses of 2 separate investigators using the above criteria (3 analyses per investigator), yielded a correlation coefficient of 0.97.

Data Analysis

Each subject's pre-training and post-training test results were presented in tables and graphs. Also, the improvement (or lack thereof) of each subject's $\dot{V}O_2$ max and AT was recorded. Since this is a descriptive study, no statistical analysis was done.

Chapter 4

RESULTS

The general characteristics of each subject are presented in Table 1. The results of pre-training (pre-t) and post-training (post-t) tests for individual subjects are presented in Tables 3 to 9, as well as graphical representations of the pre-t and post-t tests' alterations in gas exchange responses are presented in Figures 1 to 7.

Subject 1 (S1)

The results of S1 are shown in Table 3 and Figure 1.

The absolute value of $\dot{V}O_2$ max was increased by 21.6%, from 4.030 to 4.900 $L \cdot min^{-1}$. The relative value of $\dot{V}O_2$ max was increased by 26.4%, from 52.2 to 66.0 $ml \cdot Kg^{-1} \cdot min^{-1}$.

The total test time, or the time to reach $\dot{V}O_2$ max was 13 minutes (min) and 30 seconds (sec) during the pre-t test and 17 min during the post-t test, the time increase was 25.9%.

The maximum (max) workload was 3.00 Kp during the pre-t while the post-t test max workload increased to 3.50 Kp, the percentage change was 16.7%.

The total power output (PO) was increased by 41.7% from the pre-t test and post-t PO totals of 18,192 Kpm and 25,779 Kpm, respectively.

The maximum heart rate (HR max) decreased by 1.1%, from 187 to 185 beats·min^{-1} (bpm) during the post-t test.

The average stroke rates of the pre-t and post-t tests were 29 and 27 strokes · min^{-1} (spm), respectively, the percentage decrease was 6.9%.

The AT percent of $\dot{V}O_2$ max was increased from 77.8% to 85.1% following the training program, the percent increase was 9.4%.

The time taken to reach AT was 5 min during the pre-t test and 11 min 30 sec during the post-t test, the improvement rate was 130%.

The workloads at AT in the pre-t and the post-t tests were 2.00 Kp and 2.75 kp, respectively, the percentage increase was 37.5%.

The PO at AT was 5,212 Kpm during the pre-t test and14,888 kpm during the post-t, the percentage increase was186%.

The absolute value of $\dot{V}O_2$ max at AT was 3.136 L · min^{-1} during the pre-t test and 4.171 L · min^{-1} during the post-t test, the percentage increase was 33.0%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 42.0 ml · Kg^{-1} · min^{-1} during the pre-t test and 51.6 ml · Kg^{-1} · min^{-1} during the post-t test, the percentage improvement was 34.8%.

The HRs at AT were 161 and 172 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 6.8%.

Table 3

Pre- and Post-Training Test Results of Subject 1

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	13:30	17:00	25.9 ↑
Maximum Workload (Kp)	3.00	3.50	16.7 ↑
Total Power Output (Kpm)	18,192	25,779	41.7 ↑
Average Stroke Rate (stks·min^{-1})	29	27	6.9 ↓
$\dot{V}O_2$ max L·min^{-1}	4.030	4.900	21.6 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	52.2	66.0	26.4 ↑
Maximum Heart Rate (bts·min^{-1})	187	185	1.1↓
AT % of $\dot{V}O_2$ max	77.8	85.1	9.4 ↑
Time at AT	5:00	11:30	130 ↑
Workload at AT	2.00	2.75	37.5 ↑
Power Output at AT	5,212	14,888	186 ↑
$\dot{V}O_2$ L·min^{-1} at AT	3.136	4.171	33.0 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	42.0	56.6	34.8 ↑
Heart Rate at AT	161	172	6.8 ↑

↑ : Increase, ↓ : Decrease.

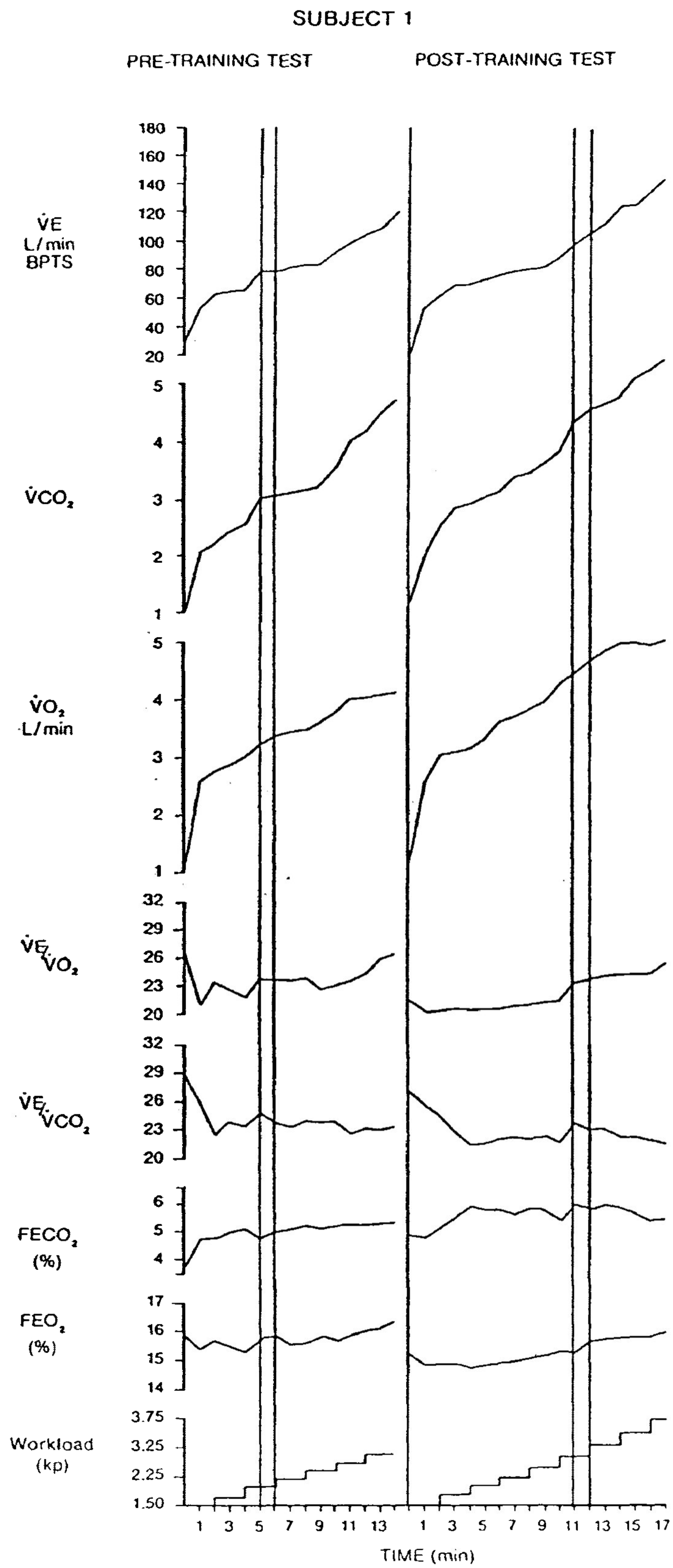

Figure 1: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Subject 2 (S2)

The results of S2 are shown in Table 4 and Figure 2.

The absolute value of $\dot{V}O_2$ max was increased by 22.9%, from 4.010 to 4.929 L · min^{-1}. The relative value of $\dot{V}O_2$ max, was increased by 15.4%, from 53.3 to 61.5 ml · Kg^{-1} · min^{-1}.

The total test time, or the time to reach $\dot{V}O_2$ max was 11 min 30 sec during the pre-t test and 14 min during the post-t test, the time increase was 21.7%.

The max workload was 2.75 Kp during the pre-t while the post-t test max workload increased to 3.00 Kp, the percentage change was 9.1%.

The total PO was increased by 26.3% from the pre-t test and the post-t PO totals of 14,284 kpm and 18,037 Kpm, respectively.

The HR max decreased by 2.0%, from 202 to 198 bpm during the post-t test.

The average stroke rates of the pre-t and the post-t tests were 30 and 28 spm, respectively, the percentage decrease was 6.7%.

The AT percent of $\dot{V}O_2$ max was decreased from 84.0% to 80.5% following the training program, the percent decrease was 4.2%.

The time taken to reach AT was 4 min during the pre-t test and 9 min and 30 sec during the post-t test, there was a time improvement of 137.5%.

The workloads at AT in the pre-t and the post-t tests were 1.75 kp and 2.50 Kp, respectively, the workload was increased by 42.9%.

The PO at AT was 3,932 Kpm during the pre-t test and 10,535 Kpm during the post-t test, the improvement rate was 168%.

The absolute value of $\dot{V}O_2$ max at AT was 3.395 $L \cdot min^{-1}$ during the pre-t test and 3.969 $L \cdot min^{-1}$ during the post-t test, the percentage increase was 16.9%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 45.2 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the pre-t test and 52.5 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the post-t test, the percentage improvement was 16.2%.

The HRs at AT were 177 and 180 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 1.7%.

<u>Subject 3 (S3)</u>

The results of S3 are shown in Table 5 and Figure 3.

The absolute value of $\dot{V}O_2$ max was increased by 15.4%, from 4.513 to 5.270 $L \cdot min^{-1}$. The relative value of $\dot{V}O_2$ max was increased by 11.0%, from 60.0 to 66.6 $ml \cdot Kg^{-1} \cdot min^{-1}$.

The total test time, or the time to reach $\dot{V}O_2$ max was 14 min during the pre-t test and 18 min during the post-t test, the time increase was 28.6%.

The pre-t test max workload was 3.00 Kp, while the post-t test max workload was increased to 3.75 Kp, the percentage change was 25.0%.

The total PO was increased by 22.6% from the pre-t test and post-t test totals of 18,962 kpm and 23,247 Kpm, respectively.

The HR max decreased by 1.6%, from 189 to 186 bpm during the post-t test.

The average stroke rate during the pre-t and post-t tests were 28 and 29 spm, respectively, the percentage increase was 3.6%.

The AT percent of $\dot{V}O_2$ max was increased from 74.3% to 82.1% following the training program, the percent increase was 10.5%.

The time taken to reach AT was 6 min and 15 sec during the pre-t test and 10 min and 15 sec during the post-t test, there was an improvement of 64.0%.

The workload at AT in the pre-t and post-t tests were 2.25 kp and 2.75 Kp, respectively, the percent increase was 22.2%.

The PO at AT was 6,662 Kpm during the pre-t test and 12,052 Kpm during the post-t, the PO was increased by 80.9%.

The absolute value of $\dot{V}O_2$ max at AT was 3.355 $L \cdot min^{-1}$ during the pre-t test and 4.327 $L \cdot min^{-1}$ during the post-t, the percent increase was 29.0%.

The body adjusted value of $\dot{V}O_2$ max at AT was 44.6 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the pre-t test and 54.7 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the post-t test, the percentage improvement was 22.6%.

The HRs at AT were 163 and 164 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 0.6%.

Subject 4 (S4)

The results of S4 are shown in Table 6 and Figure 4.

The absolute value of $\dot{V}O_2$ max was increased by 7.6%, from 3.797 to 4.086 $L \cdot min^{-1}$. The relative value of $\dot{V}O_2$ max was increased by 4.2%, from 61.6 to 64.2 $ml \cdot Kg^{-1} \cdot min^{-1}$.

The total test time, or the time to reach $\dot{V}O_2$ max was 11 min during the pre-t test and 13min during the post-t test, the time increase was 18.2%.

The max workload was 2.75 Kp during the pre-t test, while the max workload during the post-t test increased to 3.00 Kp, the percent increase was 9.1%.

The total PO was increased by 22.9% from the pre-t test and post-t test totals of 14,319 kpm and 17,602 Kpm, respectively.

The HR max decreased by 0.5%, from 215 to 214 bpm during the post-t test.

The average stroke rate of the pre-t and post-t tests were 30 and 29 spm, respectively, the percentage decrease was 3.3%.

The AT percent of $\dot{V}O_2$ max was increased from 86.8% to 88.8% following the training program, the percent increase was 2.3%.

The time taken to reach AT was 4 min during the pre-t test and 5min and 15 sec during the post-t test, the time was increased by 58.3%.

The workloads at AT in the pre-t and the post-t test, were 2.00 kp and 2.50 kp, respectively, the workload was increased by 25.0%.

The PO at AT was 3,948 Kpm during the pre-t test and 9,322 Kpm during the post-t test, the PO was increased by 136.1%.

The absolute value of $\dot{V}O_2$ max at AT was 3.330 $L \cdot min^{-1}$ during the pre-t test and 3.813 $L \cdot min^{-1}$ during the post-t test, the percentage increase was 14.5%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 54.0 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the pre-t test and 59.9 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the post-t test, the percentage increase was 10.9%.

The HRs at AT were 202 and 203 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 0.5%.

Table 4

Pre- and Post-Training Test Results of Subject 2

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	11:30	14:00	21.7 ↑
Maximum Workload (Kp)	2.75	3.00	9.1 ↑
Total Power Output (Kpm)	14,284	18,037	26.3 ↑
Average Stroke Rate (stks·min^{-1})	30	28	6.7 ↓
$\dot{V}O_2$ max L·min^{-1}	4.010	4.929	22.9 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	53.3	61.5	15.4 ↑
Maximum Heart Rate (bts·min^{-1})	202	198	2.0 ↑
AT % of $\dot{V}O_2$ max	84.0	80.5	4.2 ↓
Time at AT	4:00	9:30	137.5 ↑
Workload at AT	1.75	2.50	42.9 ↑
Power Output at AT	3,932	10,535	168 ↑
$\dot{V}O_2$ L · min^{-1} at AT	3.395	3.969	16.9 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	45.2	52.5	16.2 ↑
Heart Rate at AT	177	180	1.7 ↓

↑ : Increase, ↓ : Decrease.

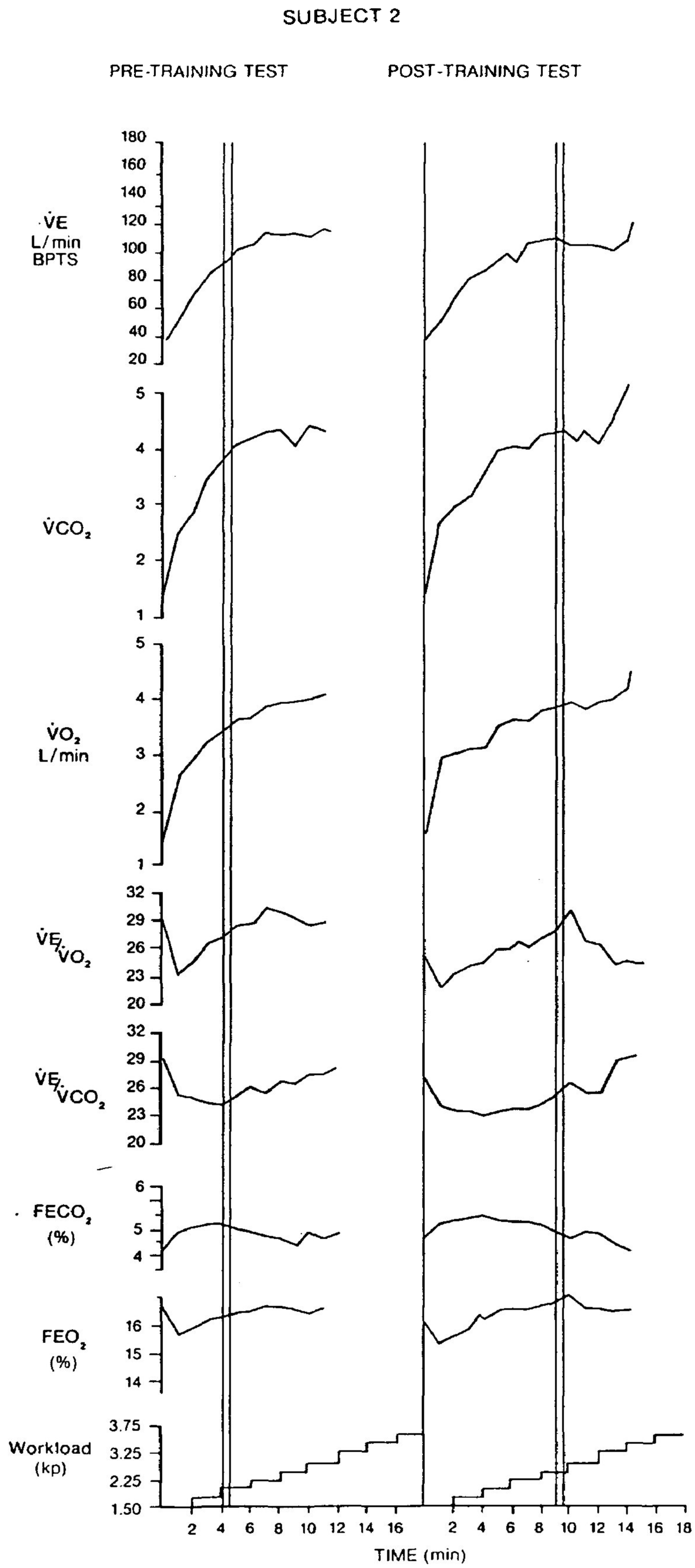

Figure 2: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Table 5

Pre- and Post-Training Test Results of Subject 3

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	14:00	18:00	28.6 ↑
Maximum Workload (Kp)	3.00	3.75	25.0 ↑
Total Power Output (Kpm)	18,962	23,247	22.6 ↑
Average Stroke Rate ($stks \cdot min^{-1}$)	28	29	3.6 ↑
$\dot{V}O_2$ max $L \cdot min^{-1}$	4.513	5.207	15.4 ↑
$\dot{V}O_2$ $ml \cdot Kg^{-1} \cdot min^{-1}$	60.0	66.6	11.0 ↑
Maximum Heart Rate ($bts \cdot min^{-1}$)	189	186	1.6 ↓
AT % of $\dot{V}O_2$ max	74.3	82.1	10.5 ↑
Time at AT	6:15	10:15	64.0 ↑
Workload at AT	2.25	2.75	22.2 ↑
Power Output at AT	6,662	12,052	80.9 ↑
$\dot{V}O_2$ $L \cdot min^{-1}$ at AT	3.355	4.327	29.0 ↑
$\dot{V}O_2$ $ml \cdot Kg^{-1} \cdot min^{-1}$ at AT	44.6	54.7	22.6 ↑
Heart Rate at AT	163	164	0.6 ↑

↑ : Increase, ↓ : Decrease.

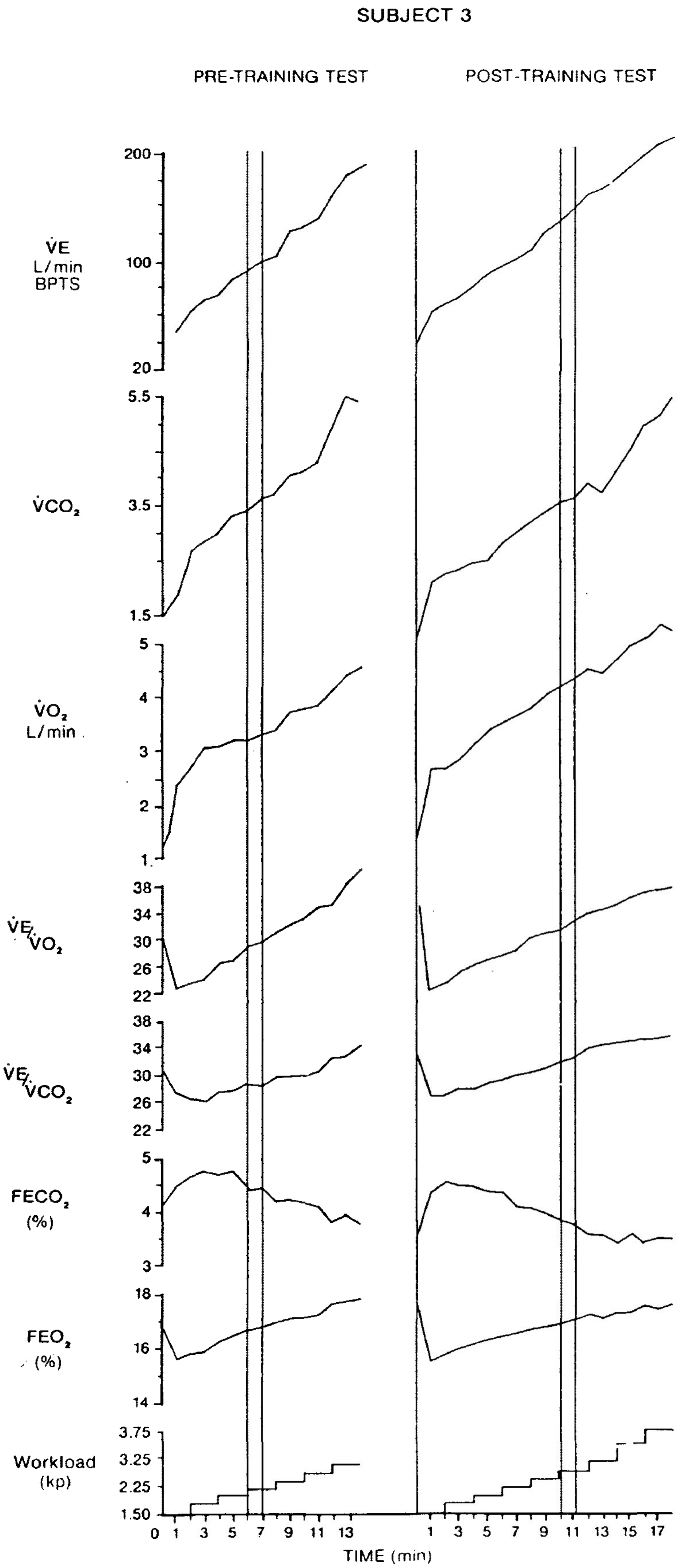

Figure 3: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Table 6

Pre- and Post-Training Test Results of Subject 4

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	11:00	13:00	18.2 ↑
Maximum Workload (Kp)	2.75	3.00	9.1 ↑
Total Power Output (kpm)	14,319	17,602	22.9 ↑
Average Stroke Rate (stks·min^{-1})	30	29	3.3 ↓
$\dot{V}O_2$ max L·min^{-1}	3.797	4.086	7.6 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	61.6	64.2	4.2 ↑
Maximum Heart Rate (bts·min^{-1})	215	214	0.5 ↓
AT % of $\dot{V}O_2$ max	86.8	88.8	2.3 ↑
Time at AT	5:15	8:15	57.1 ↑
Workload at AT	2.00	2.50	25.0 ↑
Power Output at AT	3,948	9,322	136.1 ↑
$\dot{V}O_2$ L·min^{-1} at AT	3.330	3.813	14.5 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	54.0	59.9	10.9 ↑
Heart Rate at AT	202	203	0.5 ↑

↑ : Increase, ↓ : Decrease.

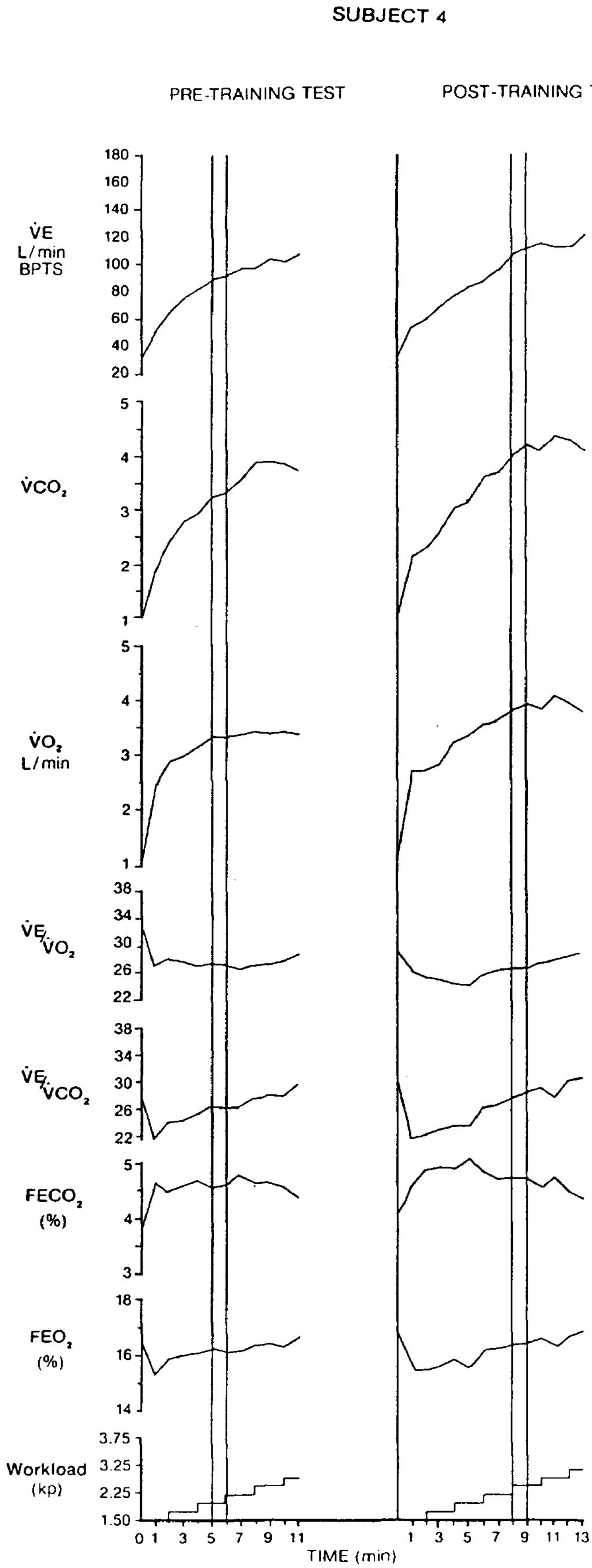

Figure 4: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Subject 5 (S5)

The results of S5 are shown in Table 7 and Figure 5.

The absolute value of $\dot{V}O_2$ max was increased by 4.6%, from 4.990 to 5.221 L · min^{-1}. The relative value of $\dot{V}O_2$ max was increased by 7.4%, from 64.7 to 69.5 ml · Kg^{-1} · min^{-1} .

The total test time, or the time to reach $\dot{V}O_2$ max, was10 min during the pre-t test and 14 min during the post-t test, the time increase was 40%.

The max workload was 2.50 Kp during the pre-t, while the post-t test max workload increased to 3.00 Kp, the percentage change was 20.0%.

The total PO increased by 53.8% from the pre-t test and post-t test totals of 12,486 kpm and 19,210 Kpm, respectively.

The HR max increased by 3.6%, from196 to 203 bpm during the post-t test.

The average strokes rate during the pre-t and post-t tests were 29 and 28 spm, respectively, the percentage decrease was 3.4%.

The AT percent of $\dot{V}O_2$ max was increased from 64.9% to 69.5% following the training program, the percentage increase was 7.4%.

The time taken to reach AT was 5 min and 30 sec during the pre-t test and 8 min and 30 sec during the post-t test, the time was increase by 56.6%.

The workloads at AT during the pre-t and post-t tests, were 2.00 kp and 2.50 Kp, respectively, the workloadat AT was increase by 25.0%.

The PO at AT was 5,338 Kpm during the pre-t test and 9,526 kpm during the post-t test, the percentage increase was 78.5%.

The absolute value of $\dot{V}O_2$ max at AT was 3.906 L · min^{-1} during the pre-t test and 4.239 L · min^{-1} during the post-t test, the percentage improvement was 8.5%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 50.6 ml · Kg^{-1} · min^{-1} during the pre-t test and 56.4 ml · Kg^{-1} · min^{-1} during the post-t test, the percentage increase was 11.5%.

The HRs at AT were 180 and 188 bpm for the pre-t and post-t tests, respectively, the HR was increased by 4.4%.

Subject 6 (S6)

The results of S6 are shown in Table 8 and Figure 6.

The absolute value of $\dot{V}O_2$ max was increased by 2.0%, from 4.917 to 5.013 L · min^{-1}. The relative value of $\dot{V}O_2$ max was increased by 4.3%, from 53.9 ml · kg · min^{-1} to 56.2 ml · Kg^{-1} · min^{-1} .

The total test time, or the time to reach $\dot{V}O_2$ max was14 min during the pre-t test and16 min during the post-t test, the time was increased by14.3%.

The max workload was 3.00 Kp during the pre-t-test, while the post-t test max workload increased to 3.50 Kp, the percentage change was 16.7%.

The total PO increased by 20.9% from the pre-t test and post-t test totals of18,505 kpm and 22,367 Kpm, respectively.

The HR max decreased by 5.0%, from 198 to188 bpm during the post-t test.

The average stroke rates of the pre-t and post-t tests were 29 and 27 spm, respectively, a stroke rate decrease of 6.9%.

The AT percent of $\dot{V}O_2$ max was increased from 76.7% to 89.2% following the training program, the percentage increase was 16.3%.

The time taken to reach AT was 6 min during the pre-t test and 9 min and 15 sec during the post-t test, the time was increased by 54.2%.

The workload at AT was 2.00 Kp during the pre-t test and 2.50 Kp during the post-t test, respectively, the workload was increased by 25.0%.

The PO at AT was 6,340 Kpm during the pre-t test and 10,825 kpm during the post-t test, the increased rate was 70.7%.

The absolute value of $\dot{V}O_2$ max at AT was 3.775 $L \cdot min^{-1}$ during the pre-t test and 4.471 $L \cdot min^{-1}$ during the post-t test, the percentage increase was 18.4%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 45.2 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the pre-t test and 50.1 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the post-t test, the percentage improvement was 21.0%.

The HRs at AT were 173 and 175 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 1.2%.

<u>Subject 7 (S7)</u>

The results of S7 are shown in Table 9 and Figure 7.

The absolute value of $\dot{V}O_2$ max was increased by 5.9%, from 6.287 $L \cdot min^{-1}$ to 6.658 $L \cdot min^{-1}$. The relative value of $\dot{V}O_2$ max was increased by 7.0%, from 70.4 $ml \cdot kg \cdot min^{-1}$ to 75.3 $ml \cdot Kg^{-1} \cdot min^{-1}$.

The total test time, or the time to reach $\dot{V}O_2$ max was17 min during the pre-t test, and19 min during the post-t test, the time increase was 11.8%.

The max workload of 3.75 Kp was the same in both pre-t and post-t tests.

The total PO was increased by16.3% from the pre-t test and post-t test PO totals of 25,474 kpm and 29,627 Kpm, respectively.

The HR max increased by 1.7%, from 180 to183 bpm during the post-t test.

The average stroke rates of the pre-t and post-t tests were 29 and 28 spm, respectively, the percentage decrease was 3.4%.

The AT percent of $\dot{V}O_2$ max was increased from 81.3% to 87.3% following the training program, the percentage increase was 7.4%.

The time taken to reach AT was 12 min and 30 sec min during the pre-t test and 14 min and 45 sec during the post-t test, the time was increased by 18.0%.

The workloads at AT during the pre-t and the post-t tests, were 3.00kp and 3.50 kp, respectively, the percentage increase was 16.7%.

The PO at AT was 16,362 Kpm during the pre-t test and 22,138 Kpm during the post-t test, the improvement rate was 35.3%.

The absolute value of $\dot{V}O_2$ max at AT was 5.110 $L \cdot min^{-1}$ during the pre-t test and 5.812 $L \cdot min^{-1}$ during the post-t test, the percentage change was 13.7%.

The body weight adjusted value of $\dot{V}O_2$ max at AT was 57.2 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the pre-t test and 65.8 $ml \cdot Kg^{-1} \cdot min^{-1}$ during the post-t test, a percentage increase of 15.0%.

The HRs at AT were 168 and 174 bpm for the pre-t and post-t tests, respectively, the HR at AT was increased by 3.6%.

Table 7

Pre- and Post-Training Test Results of Subject 5

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	10:00	14:00	40.0 ↑
Maximum Workload (Kp)	2.50	3.00	20.0 ↑
Total Power Output (Kpm)	12,486	19,210	53.8 ↑
Average Stroke Rate (stks·min^{-1})	29	28	3.4 ↓
$\dot{V}O_2$ max L·min^{-1}	4.990	5.221	4.6 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	64.7	69.5	7.4 ↑
Maximum Heart Rate (bts·min^{-1})	196	203	3.6 ↑
AT % of $\dot{V}O_2$ max	78.2	81.2	3.8 ↑
Time at AT	5:30	8:30	56.6 ↑
Workload at AT	2.00	2.50	25.0 ↑
Power Output at AT	5,338	9,526	78.5 ↑
$\dot{V}O_2$ L·min^{-1} at AT	3.906	4.239	8.5 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	50.6	56.4	11.5 ↑
Heart Rate at AT	180	188	4.4 ↑

↑ : Increase, ↓ : Decrease.

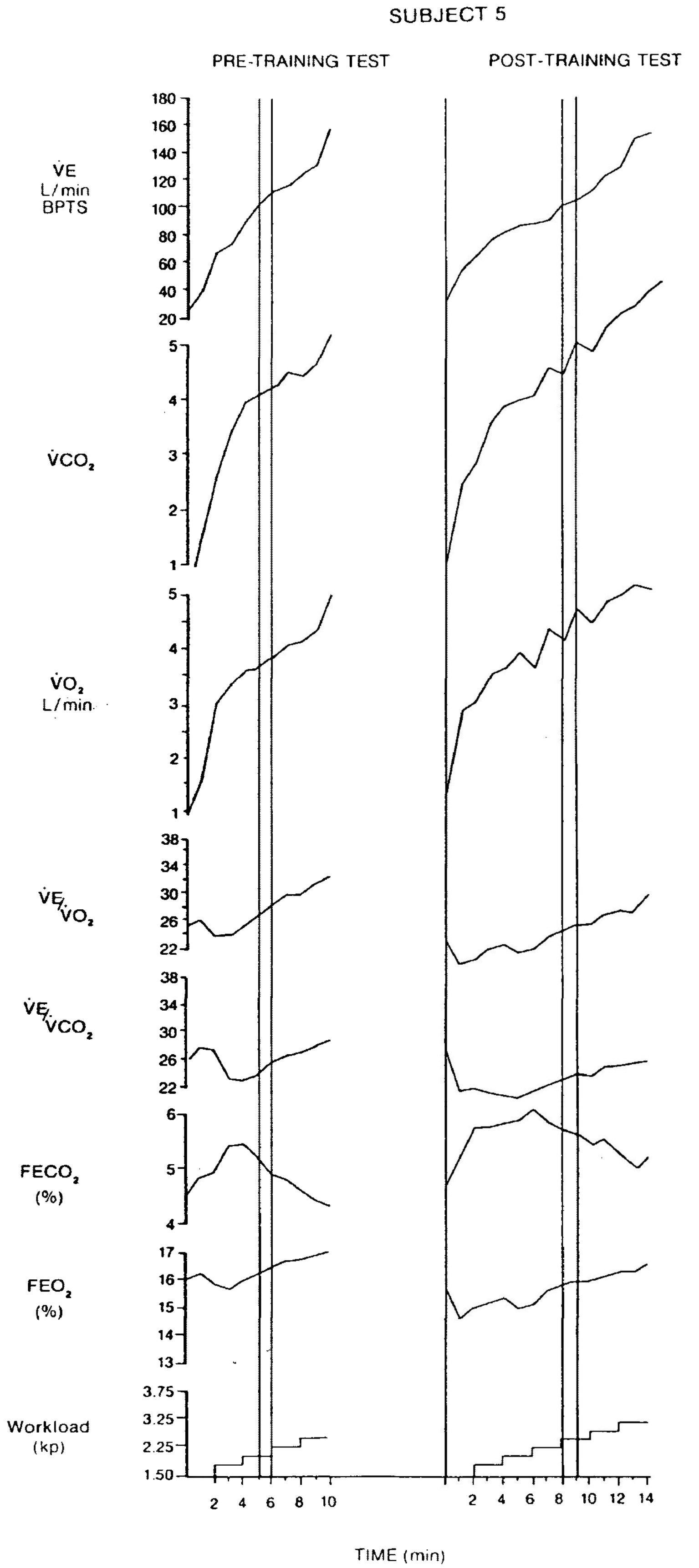

Figure 5: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Table 8

Pre- and Post-Training Test Results of Subject 6

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	14:00	16:00	14.3 ↑
Maximum Workload (Kp)	3.00	3.50	16.7 ↑
Total Power Output (kpm)	18,505	22,367	20.9 ↑
Average Stroke Rate (stks·min^{-1})	29	27	6.9 ↓
$\dot{V}O_2$ max L·min^{-1}	4.917	5.013	2.0 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	53.9	56.2	4.3 ↑
Maximum Heart Rate (bts·min^{-1})	198	188	5.0 ↓
AT % of $\dot{V}O_2$ max	76.7	89.2	16.3 ↑
Time at AT	6:00	9:15	54.2 ↑
Workload at AT	2.00	2.50	25.0 ↑
Power Output at AT	6,340	10,825	70.7 ↑
$\dot{V}O_2$ L·min^{-1} at AT	3.775	4.471	18.4 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	41.4	50.1	21.0 ↑
Heart Rate at AT	173	175	1.2 ↑

↑ : Increase, ↓ : Decrease.

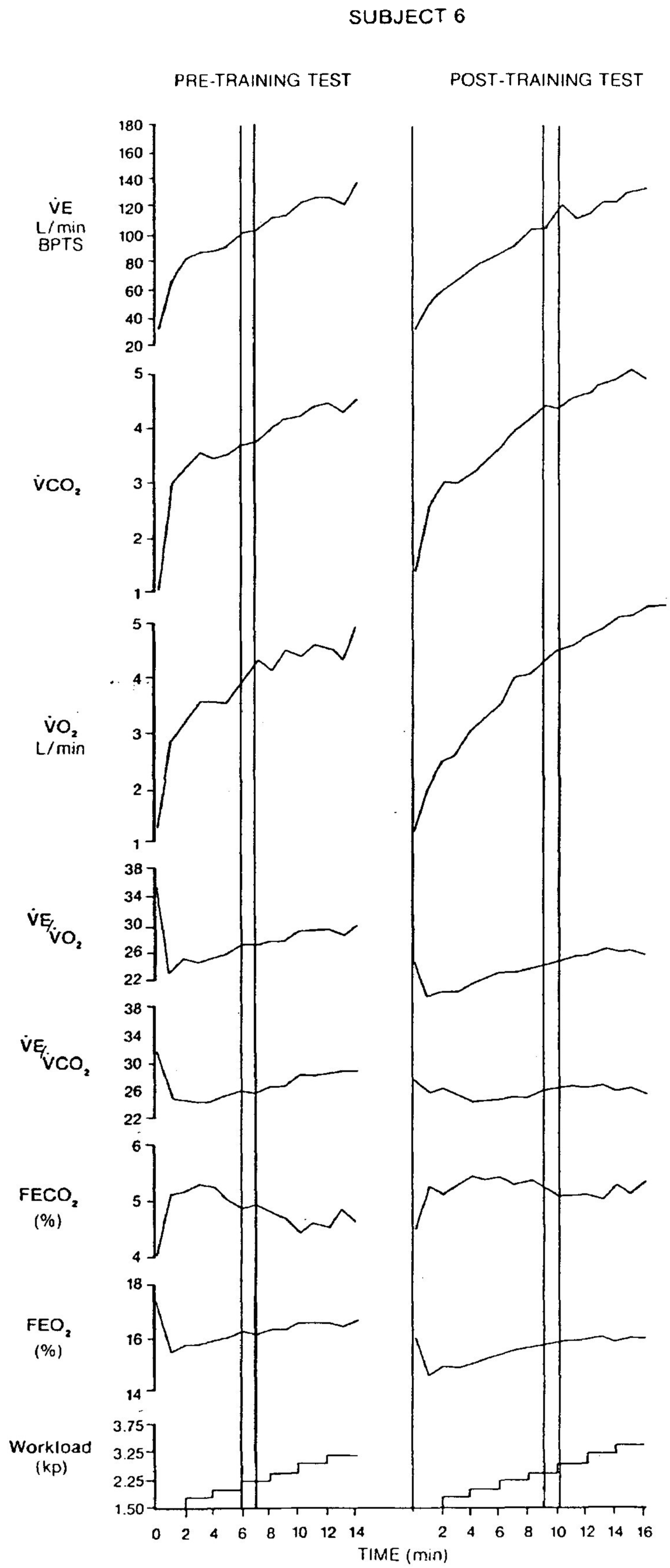

Figure 6: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Table 9

Pre- and Post-Training Test Results of Subject 7

Variables	Pre-Training Test	Post-Training Test	% Change
Total Test Time (min:sec)	17:00	19:00	11.8 ↑
Maximum Workload (Kp)	3.75	3.75	=
Total Power Output (Kpm)	25,474	29,627	16.3 ↑
Average Stroke Rate (stks·min^{-1})	29	28	3.4 ↓
$\dot{V}O_2$ max L·min^{-1}	6.287	6.658	5.9 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1}	70.4	75.3	7.0 ↑
Maximum Heart Rate (bts·min^{-1})	180	183	1.7 ↑
AT % of $\dot{V}O_2$ max	81.3	87.3	7.4 ↑
Time at AT	12:30	14:45	18.0 ↑
Workload at AT	3.00	3.50	16.7 ↑
Power Output at AT	16,362	22,138	35.3 ↑
$\dot{V}O_2$ L·min^{-1} at AT	5.110	5.812	13.7 ↑
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	57.2	65.8	15.0 ↑
Heart Rate at AT	168	174	3.6 ↑

↑ : Increase, ↓ : Decrease, = : No change

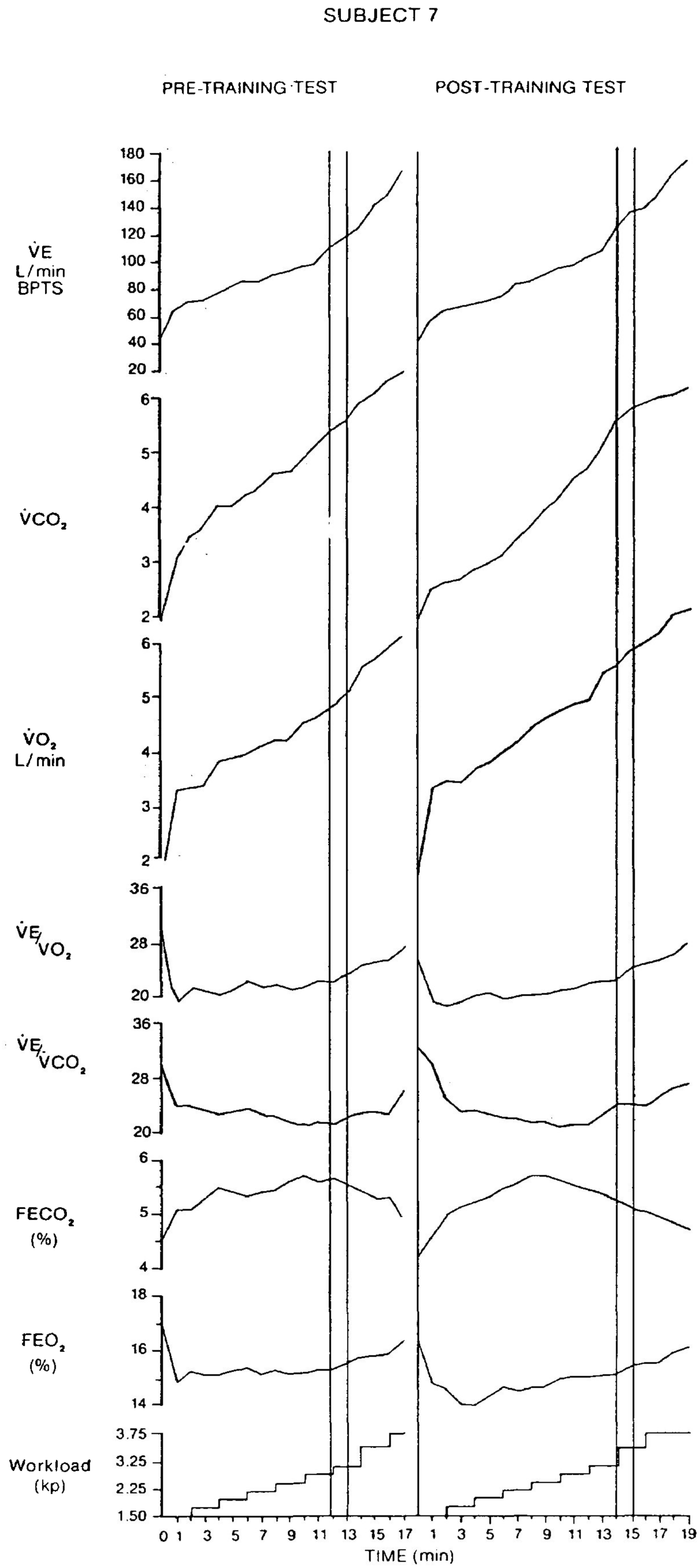

Figure 7: Representative plots of ventilation and respiratory gas exchange responses during an incremental rowing ergometer Pre-Training and Post-Training tests. The AT occurs at the time period represented by the two vertical lines.

Summary

After the 8-week training program, improvements were found in the results of the post-t test as compared with the pre-t test results. The following statements apply to all subjects and summarize the data which illustrate this improvement :

The absolute and relative values of $\dot{V}O_2$ max were increased within the range of 1.8% to 22.9% and -4.2% to 16.3%, respectively.

The AT percent of $\dot{V}O_2$ max was increased within the range of -4.2% to16.3% .

The total test time was increased during the post-t tests within the range of 11.8% to 40.0%.

The total PO, as well as, the max workload, were increased during the post-t tests within the range of 16.3% to 53.8% and 9.1% to 25.0%, respectively.

The time, workload and PO at AT were increased during the post-t tests within the range of 18.0% to 137.5%, 16.7% to 42.9%, and 35.3% to 186%, respectively.

All of the subjects reached AT at higher absolute and relative values of $\dot{V}O_2$max during the post-t test, and the improvements were within the range of 8.5% to 33.0% and 11.5% to 34.8%, respectively.

The maximum HRs were increased within the ranges of 1.0% to 3.6% in S2, S5 and S7, during the post-t test, and were decreased within the range of 1.0% to 5.0% in S1, S3, S4 and S6.

The HRs at AT were increased during the post-t test within the range of 1.10% to 6.8% in S1, S3, S4, S5, S6, and S7, however, in S2 was decreased by 1.7%.

The average stroke rates were decreased during the post-t test within the range of 3.3% to 6.9%, respectively.

The rowing performance was improved in all subjects following the 8-week training program.

Chapter 5

DISCUSSION

Results from cross-sectional and longitudinal studies suggest that endurance training produces changes in $\dot{V}O_2$ max and AT values, i.e., the AT occurs at a higher percentage of $\dot{V}O_2$ max following training. For example, Costill (1970) and Costill et al. (1973) reported that well-trained endurance athletes could exercise at 70% of $\dot{V}O_2$ max with little or no change in blood LA values. These athletes also were able to maintain, for 30 minutes, a running pace which required an energy cost close to 90% of $\dot{V}O_2$ max. From this information, AT values for these athletes would appear to approximate 85% $\dot{V}O_2$ max. This value is higher than the normally reported values of 50 to 55% and 70 to 80% $\dot{V}O_2$ max for untrained and trained individuals, respectively (Davis et al.,1976; MacDougall,1977). Data from endurance training programs have also indicated improvements in relative AT values. Davis et al. (1979) and Sady et al. (1980) reported that relative AT values increased from 49% to 57% $\dot{V}O_2$ max following 8 to10 weeks of training. The findings of this study are in agreement with the previous investigations.

The effects of high-intensity IT on relative AT values are not well documented. Since it has been proposed by Skinner and McLellan (1980) that the ventilatory and LA responses during an incremental work test reflect changes in metabolic substrate flux within the muscle fibres that are being recruited, high-intensity IT, which demands fast energy turnover, should be associated with an enhanced carbohydrate utilization within specific muscle fibres. For example, Costill et al. (1976a) reported that the highest muscle phosphorylase (MP) activity was found among sprint and middle-distance runners who were utilizing high-intensity IT. These enzyme levels were not related to fibre composition and were more than two times greater than the MP activity of endurance athletes. Therefore, high-intensity IT appears to increase an individual's ability to utilize carbohydrate as a fuel substrate. It may also produce a greater glycolytic than oxidative substrate flux. From the results of this study, as well as, from these previous investigations, it is apparent that endurance training increases AT values, whereas the effects of high-intensity IT are essentially unknown.

In this study, the non-invasive technique was used to detect the AT. The test-retest reliability coefficient value of 0.97 for the determination of AT is higher than the value of 0.95 established by Davis et al. (1976) but is comparable to the coefficient value of 0.96 obtained by Davis et al. (1979). Absolute ($L \cdot min^{-1}$) and relative (% $\dot{V}O_2$ max) AT values for the two tests were not different. This suggests that the non-invasive estimates of AT are also reproducable.

The relative values of $\dot{V}O_2$ max (see Tables 3, 5, 7 and 9) of the subjects S1, S3, S5 and S7 in this study are comparable to previous data on well-trained endurance athletes (Costill et al., 1976a). The $\dot{V}O_2$ max values approaching 60 $ml \cdot kg^{-1} \cdot min^{-1}$ for S2 and S6 are similar to values reported for trained individuals (Gollnick et al. 1972), and to club level rowers (Hagerman and Mikelson, 1979; Vrijens and Bouckaert, 1984).

The higher relative values of $\dot{V}O_2$ max observed for S1, S3, S4, S5, and S7 (see Tables 3, 5, 6, 7 and 9) are comparable to the interpreted data presented by Costill (1970), but are lower than the mean value of 72 $\dot{V}O_2$ max $ml \cdot kg^{-1} \cdot min^{-1}$ determined by Hagerman et al. (1979). This later study, however, used higher calibre rowers.

The values of AT obtained in this study (80.5 to 89.2% of $\dot{V}O_2$ max) are comparable to the mean values of 83% $\dot{V}O_2$ max obtained by Mickelson and Hagerman (1982). Thus, individuals involved in endurance training appear to have higher AT values than individuals participating in other types and intensities of exercise (Costill et al.,1970; Withers et al.,1981; Stegman, 1981; Weltman & Katch,1979). Since national calibre subjects in this study had higher values of $\dot{V}O_2$ max and AT than the provincial calibre subjects, the magnitude of the training influence may depend on other factors: for example, it cannot be disregarded that these differences resulted because national calibre subjects had been training for more years, or had trained at higher intensities. All the subjects, however, were involved in endurance training prior to the study.

The difference in AT among the subjects might also be related to the influence of training on a given muscle fibre composition. It has been reported that well-trained endurance athletes tend to have a higher portion of ST fibres with specifically trained muscle groups (Costill et al., 1976b; Gollnick et al.,1972; Bergh, Thorstensson, Sjodin, Hulten, Piehl and

Karlsson, 1978; Larsson and Forsberg,1980). Bergh et al. (1978) have shown shown a positive relationship between high $\dot{V}O_2$ max values and a large percentage of ST muscle fibres in the gastrognemius and vastus lateralis of elite athletes. The high oxidative characteristics present in the vastus lateralis, one of the primary muscles used in rowing (Larsson and Forsberg, 1980), may be representative of an overall increase in the oxidative capacity of the muscles utilized in rowing. It, therefore, appears that highly trained oarsmen, along with other endurance-trained athletes, have a greater mitochondrial density along with an increase in the oxidative enzymes, which may allow them to oxidize large quantities of LA during exercise. Although training appears to have no influence on the percentage of ST fibre distribution (Saltin et al.,1977), it may enhance the oxidative potential of all fibre types (Saltin et al., 1977). Ivy et al. (1980) reported that AT is related both to the oxidative potential of the muscle and to the percentage of ST fibre distribution; therefore, it may be that relative AT values are the result of a training effect (i.e., oxidative potential) on a given muscle fibre distribution. If so, the endurance athletes should have higher AT values due to the influence of training or the high proportion of ST fibres which are more likely to be recruited during the initial workloads of the rowing ergometer test.

Type of training appears to influence $\dot{V}O_2$ max and AT values. The fact that national calibre subjects had higher values than provincial calibre subjects, suggests that high intensity IT, although enhancing the oxidative potential of all fibre types (Saltin et al.,1977), may lead to a greater dependence on carbohydrate metabolism at a given relative workload.

Endurance training appears, from the results of this study, to augment AT values in the range of 2.3% to 16.3% of $\dot{V}O_2$ max as observed in subjects 1, 3, 4, 5, 6 and 7, with an exception of subject 2 which showed 4.2% decrease. The mechanism whereby the type of training affects AT values cannot be established from this data. It is possible, however, that endurance training, which is known to augment the relative proportion of FFA oxidation at a given PO (Holloszy, 1977), produces increased inhibition of carbohydrate flux through glycolysis and the Kreb's cycle due to elevated sarcoplasmic citrate concentrations and mitochondrial acetyl CoA levels (Newsholme, 1977). Conversely, high-intensity IT could lead to an augmented carbohydrate flux due to the fast energy turnover required. As a result, AT may occur at lower relative values (Skinner and McLellan, 1980) due to an earlier dependence on an anaerobic, rather than an oxidative, carbohydrate flux within the muscle fibres being recruited.

The degree of improvement in $\dot{V}O_2$ max and AT following the 8 weeks of training is in agreement with other reports for both CT (McLellan and Skinner, 1981; Pollock, 1973) and IT (Rivera et al., 1980) with subjects of similar fitness levels. Further, since this improvement was found during both CT and IT, one type of training does not appear to enhance $\dot{V}O_2$ max and AT more than the other. The pattern of responses following the training program is similar to the one reported by Davis et al. (1979), and Williams et al. (1976), but the magnitude of change is less than the changes documented by these earlier investigations. This difference could be explained by the greater intensity (approximately 95% $\dot{V}O_2$ max), frequency (4 to 7 days per week) and/or duration of training (60 minutes per session for 9 weeks) used by these investigators. As mentioned before, it appears that the intensity of exercise may be a more important determinant for producing changes in $\dot{V}O_2$ max and AT with only 8 weeks of CT and IT 3 times per week. Since there was a change in $\dot{V}O_2$ max and AT with CT and IT, this may suggest that the intensity of exercise (CT: AT - 10% $\dot{V}O_2$ max and IT: AT + 10 to 25% $\dot{V}O_2$ max) was sufficient to enhance the oxidative potential and rate of FFA oxidation within the more glycolytic fibres which would be recruited during the above intensities of training. Since muscle adaptation appears to be localized in those fibres recruited during a given exercise intensity (Saltin et al., 1977), it is suggested that future research focus on the effects of a CT program with the PO maintained closer to individual AT levels.

The maximum performance time increased among all subjects (see Tables 3 to 9) after the 8 weeks of training . The results are in contrast to the findings of Eddy et al. (1977), who stated that performance time at 90% $\dot{V}O_2$ max was not affected by CTor IT programs. Since these researchers reported an increase in $\dot{V}O_2$ max (42 to 48 $ml \cdot kg^{-1} \cdot min^{-1}$) lower than the results of the present investigation, it appears that fitness level can account for the different findings. Further, the CT program used by Eddy et al (1977) consisted of 4 sessions per week at 70% $\dot{V}O_2$ max for 7 weeks, a program which was similar to the one used in this study. Although the average PO for the IT group was 50% $\dot{V}O_2$ max (IT low was 1 minute of rest), the high phase consisted of 1 minute of exercise at 100% $\dot{V}O_2$ max , which was similar to the IT high used in this study.

The major discrepancy between the CT and IT programs used by Eddy et al. (1977) and those of the present study, concerns the total PO and, as a result, the total duration of each training session. Eddy et al (1977) controlled the total PO for the CT and IT programs. The differences between the training program of the present study and those reported by Eddy et al. (1977) suggest that the duration and total PO of each exercise session were important for producing the changes observed between the two tests of maximum performance time following the 8-week program. Also, this change may reflect the improvement in the fitness level of the subjects.

Following the 8-week training program, AT occurred at greater values of $\dot{V}O_2$, PO and time (see Tables 3 to 9 and Figures 1 to 7). These values are in agreement with Davis et al. (1979). These findings indicate that the subjects were able to perform greater amounts of work without an accumulation of LA during the incremental test. This can most likely be explained by the delayed onset of LA acidosis consequent to exercise training (Holloszy, 1976), and to the fact that exercise training reduces the level of blood LA at submaximal work rates (Davis et al., 1979). Possible mechanisms which might account for an increased AT after endurance training include an improved distribution of blood flow in the trained muscles, increased oxidative capacity at the cellular level, and an alteration in the muscle fibre recruitment pattern resulting in an increased activation of the ST muscle fibres. As it has been discussed previously, there appears to be a great deal of support in the literature for each of these possible mechanisms. It is tempting to suggest that the post-training differences in the rate of change in $\dot{V}O_2$ max during the rowing test reflected the changes in relative AT values which were observed.

It is believed that the mode of exercise used in this study was specific to the rowing movement (Specificity of Training Concept, Åstrand and Rodahl,1977, p. 434-435), may have contributed to the enhancement of $\dot{V}O_2$ max and AT. Rowing ergometer training replicates the movement patterns of the actual rowing performance; therefore, the muscular adaptations are specific to rowing performance.

Tables 3 to 9, present the changes in HR at AT during the pre- and post-training tests, there were notable different ranges for HR at AT among the subjects. The AT occurred at slightly higher HR responses following the endurance training program; however, the subjects reached AT during the post-training test at greater workloads than during the pre-t test. These specific observations have been made by other investigators (Davis et al.,1979; Katch et al.,1978). Although HR cannot be used to identify the AT, it may be used to regulate training intensity above or below AT, and this requires individual assessment of HR at AT.

Another observation worth mentioning is that the subjects, during the post-training test, were able to maintain the PO required during the test by rowing at a lower stroke rate. This indicates that the mechanical efficiency of the subjects had improved during the training period.

The high AT and $\dot{V}O_2$ max outputs of oarsmen can be attributed, at least in part, to the specific nature of their training programs. Because rowing is primarily an aerobic event, a substantial percentage (75-80%) of training time is devoted to aerobic work. The effect of this type of training on both ST and FT muscle fibres has been well documented. The result is an increased of aerobic adaptations at the cellular level, most likely a result of the rigorous training regimen. The increase in oxygen utilization could, therefore, delay the deleterious effects of LA accumulation during high intensity exercise. The high AT of trained athletes may also be indicative of their increased ability to utilize LA as a fuel during exercise (Larsson and Forsberg, 1980). The increased oxidation of LA could therefore result in a diminished influence of LA at AT (Larsson and Forsberg, 1980).

The morphological, histochemical and biochemical nature of major muscles contributing to the rowing movement may also affect the AT. Oarsmen routinely train daily all year round, and their in-season regimen includes long-duration exercise at varying intensities and shorter IT sessions at very high intensity. This training program is aimed at delaying the onset of metabolic acidosis during the early part of a 2,000 meter race, developing a high aerobic power output, and increasing tolerance of high LA levels.

The main findings of the present study indicate increases in $\dot{V}O_2$ max and AT, and increases in performance times, PO and $\dot{V}O_2$ max before reaching AT following the 8 weeks of endurance training. These findings are in agreement with the results obtained from other investigations

(Bueno, 1982; Davis et al., 1976), however, because of differences in the training regimen, mode of exercise, age, fitness level of the subjects and type of exercise test, the results obtained could not always be compared with each other.

Training programs using prescriptions based on percent $\dot{V}O_2$ max or HR max without considerations of individual AT create, among the participants, multiple training stimuli which in turn result in a wide range of improvements in cardiovascular and metabolic functions. A better approach would be to make individual assessments of the AT and HR at the AT before prescribing a target HR for training intensity.

The idea that exercise should be maintained at a level above or below AT to determine training intensity more effectively according to objectives, rests on the premise that real differences exist in the exercise stress at, for example, 90% of AT compared to 110% of AT. In this regard, clear differences in $\dot{V}O_2$ kinetics and ventilatory responses have been observed above and below the AT. There is a preliminary evidence supporting this presumption (Vrijens and Bouckaert,1983). In this regard, compliance with a voluntary training program may be influenced by indiscriminately prescribed exercise which requires an individual to exercise at that level. This reveals a need for greater precision, with respect to metabolic stress, in developing training prescriptions. Prescriptions for training intensity can be developed and expressed in percent HR max with AT as the major consideration. Indeed, evidence is accumulating which suggests that training prescriptions lack metabolic specificity if they are not based on AT to some degree. Standard values for the percentage of HR max at AT, grouped by age, for example, should not be applied to individuals due to the wide range, among homogeneous subjects, of relative HR at the AT (Vrijens and Bouckaert, 1983).

For the purpose of obtaining information which can be applied to training, measurement of HR at AT may provide very useful information. Use of the HR at AT in determining intensities of training sessions could prove to be a valuable aid to both coaches and oarsmen(Mickelson & Hagerman, 1982; Vrijens and Bouckaert,1983). More specifically, the increased use of long, steady-state training sessions below an oarsman's AT are becoming more common, not only to develop aerobic power but also to train neuromuscular pathways and increase local muscular endurance. Along with this, the progressive test used to measure AT allows one to determine what percentage of an oarsman's $\dot{V}O_2$ max is elicited by a particular PO. Previously, training sessions at or near AT were determined by the calculated estimate of the coach or by the intuition of the oarsman during the training exercise. Some of this trial-and-error technique can now be eliminated and training time can be utilized more efficiently. Anaerobic threshold measurements not only point out deficiencies in aerobic conditioning, but they can also provide insight into the PO at AT, i.e.,the maximum power which can be generated while avoiding an accumulation of LA and a resultant drop in blood pH. This information along with the HR at AT, can be very important to a coach when planning or assessing land and water training sessions.

The results of this study demonstrated that $\dot{V}O_2$ max and AT can be altered with CT and IT training programs. Future research within this area of investigation should include control groups, and training at different intensities in order to determine the optimal training intensity.

There has been a great deal of controversy and discussion as to the means of measuring AT and the exact definition of AT. Although the AT reported in this study is indeed an estimate, it does give the coach and athlete a useful tool with which to evaluate relative fitness levels. At the same time, AT serves as a beneficial guide in determining the intensity of training programs for oarsmen.

The findings of this study appear to be more applicable to an individual involved in continuous, long duration athletic competitions. It may seem difficult to apply these results to the majority of endurance events or team sports which involve interval exercise. A coach should be aware, however, that specific training programs may influence AT values and endurance performance differently.

Chapter 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted to evaluate the influence of an 8-week endurance training program (continuous and interval), carried out 3 times per week, for 50 to 60 minutes each session, on the aerobic power and the anaerobic threshold of male rowers.

The research design selected for this investigation was a single subject case study. The aerobic power and AT were measured in 7 subjects, all members of the Thunder Bay Rowing Club, before (Pre-Training Test) and after (Post-Training Test) the investigative period. Following the pre-training test, training programs were designed for each subject, based on a percentage above and below the subject's AT (AT +10 to 25% $\dot{V}O_2$ max, for interval training, and AT-10% $\dot{V}O_2$ max, for continuous training, respectively). The training intensity was monitored through the subject's heart rate.

The results obtained following the training program, indicated that $\dot{V}O_2$ max values were increased in all subjects within the ranges of 1.8% to 22.9%. AT values were also increased within the ranges of 0.3% to 16.3% in subjects 1, 3, 4, 5, 6, and 7, and in subject 2 there was a decrease of 4.2%. The total test time, PO and maximum workload were also increased. Similarly, time and PO at AT were increased in all of the subjects. These findings indicated that $\dot{V}O_2$ max and AT values can be altered with rowing ergometer CT and IT training, and that AT is an important factor to consider when devising training programs.

Conclusions

Based upon the results obtained and within the limitations of the experiment in this study, the following conclusions appear justified regarding the influence of an 8-week rowing ergometer training program on the $\dot{V}O_2$ max and AT in male rowers:

1. Continuous and interval endurance training program(s) based on an individual's AT increase both $\dot{V}O_2$ max and AT.

2. Anaerobic threshold values can be used to prescribe training intensities, while HR at AT can be used to monitor these training intensities.

Recommendations

1. Perhaps the most important recommendation would be to emphasize the effect of IT with different intensities and durations in several training groups, on AT and subsequent endurance performance. These investigations may elucidate an optimal training program for enhancing an individual's capacity to perform maximal or submaximal exercise.
2. Throughout this study, it was stated that several other mechanisms of response remain unclear: for example, it would be useful to investigate the influence of FFA oxidation to account for the different

changes in AT values following a continuous or interval training program. Further, it would be interesting to isolate the intramuscular mechanism(s) responsible for determining AT values. Athough this suggestion may seem impractical, scientific techniques are now available which use single muscle fibre dissections for micro-enzymatic studies. The application of such procedures to the observed responses during incremental exercise may help to clarify the controversy in terminology which exists in the literature with respect to the AT.

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APPENDIX A

RAW DATA TABLES

Table A1

Pre-Training Test Raw Data of Subjet 1

Time min:sec	Revs No/min	St. Rt./ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.5 Kp										
0:15			31.4	0.1634	0.0398	26.0	31.3	1.207	1.003	0.83	124	15.6
0:30	305	27	36.5	0.1585	0.0412	23.1	30.2	1.579	1.209	0.77	133	20.5
0:45			50.3								139	
1:00	610	27	53.7								142	
1:15			56.1	0.1523	0.0480	20.8	25.9	2.699	2.163	0.80	145	35.0
1:30	310	28	56.0								145	
1:45			62.9								147	
2:00	615	28	64.0	0.1573	0.0477	23.2	26.1	2.754	2.455	0.89	145	35.7
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			63.5								145	
2:30	310	28	63.5								147	
2:45			61.4	0.1542	0.0502	21.9	24.8	2.803	2.480	0.88	150	36.3
3:00	610	28	63.3								150	
3:15			64.0								153	
3:30	310	28	65.0	0.1521	0.0525	21.1	23.7	3.077	2.747	0.89	155	39.9
3:45			66.0								154	
4:00	615	28	66.5								154	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			71.5	0.1563	0.0488	22.8	25.5	3.196	2.807	0.90	156	40.6
4:30	310	28	71.8								156	
4:45			74.1								160	
5:00	615	28	75.2	0.1569	0.0492	23.2	25.3	3.242	2.975	0.92	161	42.0
5:15			77.2	0.1564	0.0502	23.0	24.8	3.350	3.112	0.93	164	43.4
5:30	305	28	79.1								166	
5:45			75.3								167	
6:00	610	28	75.3	0.1557	0.0512	22.8	24.3	3.229	3.028	0.94	167	43.0
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			77.8	0.1571	0.0501	23.4	24.8	3.328	3.133	0.94	167	43.1
6:30	310	30	78.9								167	
6:45			79.2								167	
7:00	610	30	80.0	0.1552	0.0526	23.2	23.6	3.340	3.134	0.94	167	43.3
7:15			81.0								169	
7:30	305	29	81.0								168	
7:45			79.9	0.1585	0.0522	24.5	23.8	3.264	3.353	1.03	168	43.3
8:00	605	30	80.1	0.1568	0.0517	23.4	24.1	3.069	2.988	1.03	167	43.1

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			80.9								169	
8:30	305	30	81.9								171	
8:45			81.9	0.1545	0.0528	22.3	23.6	3.671	3.473	0.99	170	47.6
9:00	605	30	80.8	0.1539	0.0535	22.1	23.2	3.614	3.439	0.99	171	47.8
9:15			82.6								171	
9:30	300	31	84.9								175	
9:45			91.4	0.1567	0.0530	23.5	23.4	3.891	3.901	1.00	175	50.4
10:00	600	31	92.4	0.1562	0.0542	23.6	22.8	3.813	3.793	1.00	175	50.5

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			95.2	0.1575	0.0526	23.9	23.7	3.975	4.023	1.01	176	51.5
10:30	300	30	96.3								178	
10:45			97.4	0.1595	0.0514	25.0	24.2	3.893	4.028	1.03	181	51.5
11:00	600	30	97.7	0.1583	0.0531	24.5	23.4	3.991	4.171	1.05	181	51.7
11:15			97.9	0.1598	0.0513	25.2	24.2	3.882	4.040	1.06	182	51.6
11:30	300	32	99.4								185	
11:45			98.8	0.1585	0.0543	24.9	22.9	3.972	4.293	1.08	184	51.5
12:00	605	32	101.2	0.1592	0.0535	25.1	23.3	3.976	4.288	1.08	184	51.5

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			101.2								186	
12:30	300	32	104.7								186	
12:45			104.0	0.1607	0.0525	26.0	23.7	3.960	4.339	1.10	186	51.3
13:00	600	32	104.0	0.1612	0.0527	26.3	23.6	3.952	4.412	1.12	186	51.5
13:15			108.4	0.1620	0.0528	26.9	23.5	4.029	4.606	1.14	186	52.2
13:30	300	31	112.1	0.1609	0.0555	26.5	22.4	3.967	4.698	1.18	186	51.4

Total Test time (min:sec)	13:30
Total Number of Revolutions	8,230
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	18,192
Average Stroke Rate (stks·min^{-1})	29
$\dot{V}O_2$ max (L·min^{-1})	4.030
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	52.2
Maximum Heart Rate (bts·min^{-1})	187
AT % of $\dot{V}O_2$ max (L·min^{-1})	77.8%
Time at AT	5:00
Workload at AT	2.00
Revolutions at AT	3,065
Power Output at AT	5,212
$\dot{V}O_2$ L·min^{-1} at AT	3.136
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	42.0
Heart Rate at AT	161

Table A2

Post-Training Test Raw Data of Subject 1

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			19.9								113	
0:30	310	26	34.9	0.1532	0.0449	21.2	28.1	1.645	1.240	0.75	121	22.3
0:45			51.0	0.1483	0.0493	19.5	25.6	2.615	1.995	0.76	137	35.5
1:00	620	27	51.5								135	
1:15			58.9								135	
1:30	320	27 1/2	58.8	0.1482	0.0536	19.8	23.5	2.962	2.500	0.84	135	40.2
1:45			60.5								136	
2:00	630	27	58.5								138	
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			61.6	0.1484	0.0557	20.1	22.6	3.071	2.724	0.89	139	41.7
2:30	315	27	58.3								140	
2:45			62.2								143	
3:00	625	27	65.1	0.1485	0.0556	20.1	22.7	3.236	2.871	0.89	143	43.9
3:15			63.5								147	
3:30	320	27	63.8								148	
3:45			60.3	0.1460	0.0588	19.4	21.4	3.106	2.812	0.91	147	42.2
4:00	620	27	64.2								146	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			63.3								145	
4:30	305	27	65.8	0.1488	0.0582	20.4	21.6	3.217	3.039	0.94	146	43.7
4:45			68.0								147	
5:00	615	27	68.3								148	
5:15			68.8	0.1491	0.0575	20.5	21.9	3.352	3.140	0.94	149	45.5
5:30	310	27	67.5								149	
5:45			73.6								150	
6:00	620	27	72.0	0.1498	0.0574	20.8	21.9	3.452	3.281	0.95	153	46.9
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			78.0								157	
6:30	305	27	77.5								157	
6:45			79.7	0.1515	0.0567	21.5	22.2	3.703	3.586	0.97	157	50.3
7:00	610	27	77.1								157	
7:15			79.9								159	
7:30	310	27	79.3	0.1513	0.0581	21.6	21.7	3.678	3.659	0.99	158	49.9
7:45			78.8	0.1511	0.0585	21.6	21.5	3.466	3.301	0.98	158	49.9
8:00	615	27	78.8								157	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			86.3								160	
8:30	300	27	86.9	0.1530	0.0564	22.2	22.3	3.914	3.891	0.99	166	53.1
8:45			84.1	0.1521	0.0574	21.9	21.9	3.841	3.836	1.00	163	53.0
9:00	605	27	89.5								165	
9:15			95.1								166	
9:30	315	27	94.0	0.1519	0.0575	21.8	21.9	3.806	3.792	1.00	166	52.7
9:45			92.3	0.1553	0.0544	23.2	23.2	3.977	3.987	1.00	167	54.0
10:00	615	27	89.2								167	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			88.4								167	
10:30	310	27	93.7	0.1536	0.0566	22.5	22.2	4.159	4.213	1.01	170	56.5
10:45			92.5	0.1533	0.0575	22.5	21.9	4.111	4.223	1.03	170	55.8
11:00	620	27	93.8								170	
11:15			98.0								171	
11:30	310	27	97.1	0.1550	0.0564	23.3	22.3	4.171	4.345	1.04	172	56.6
11:45			98.6	0.1551	0.0566	23.4	22.2	4.219	4.434	1.05	172	57.3
12:00	615	27	103.8								174	

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			108.9								174	
12:30	310	27	106.2	0.1573	0.0549	24.4	22.9	4.350	4.629	1.06	175	59.1
12:45			109.3	0.1575	0.0551	24.6	22.9	4.446	4.779	1.07	177	60.4
13:00	620	27	105.2	0.1575	0.0588	24.6	22.6	4.267	4.658	1.09	177	57.9
13:15			115.6								178	
13:30	305	27	114.1	0.1578	0.0564	24.9	22.3	4.584	5.107	1.11	178	62.2
13:45			109.8	0.1563	0.0587	24.3	21.4	4.526	5.122	1.13	177	61.5
14:00	625	28	119.2	0.1572	0.0575	24.7	21.9	4.832	5.445	1.13	177	65.6

WORKLOAD 8, 3.50 Kp, changed at 14:00 minutes

14:15			119.0								180	
14:30	300	28	121.6	0.1593	0.0551	25.7	22.8	4.731	5.326	1.13	183	65.2
14:45			117.8	0.1584	0.0565	25.3	22.3	4.640	5.276	1.14	184	64.6
15:00	605	28	117.0								184	
15:15			123.2								184	
15:30	300	28	123.0	0.1580	0.0575	25.2	21.9	4.630	5.327	1.15	184	64.0
15:45			123.0	0.1580	0.0591	24.1	21.3	4.539	5.141	1.14	182	62.8
16:00	600	28	123.7								184	

WORKLOAD 9, 3.75 Kp, changed at 16:00 minutes

16:15			124.7	0.1597	0.0561	26.1	22.5	4.762	5.540	1.16	184	64.9
16:30	300	28	127.6	0.1599	0.0560	26.2	22.5	4.863	5.675	1.17	185	66.0
16:45			129.9								185	
17:00	560	28	133.3								185	

Total Test time (min:sec)	17:00
Total Number of Revolutions	10,420
Maximum Workload (Kp)	3.50
Average Stroke Rate (stks·min^{-1})	27
Total Power Output (Kpm)	25,779
$\dot{V}O_2$ max (L·min^{-1})	4.900
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	66.0
Maximum Heart Rate (bts·min^{-1})	185
AT % of $\dot{V}O_2$ max (L·min^{-1})	85.1%
Time at AT	11:30
Workload at AT	2.75
Revolutions at AT	7,105
Power Output at AT	14,888
$\dot{V}O_2$ L·min^{-1} at AT	4.171
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	56.6
Heart Rate at AT	172

Table A3

Pre-Training Test Raw Data of Subject 2

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO2	FECO2	$\dot{V}_E$ O2 L/L	$\dot{V}_E$ CO2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			39.8	0.1665	0.0431	29.0	29.0	1.374	1.372	1.00	131	18.3
0:30	310	28	35.9	0.1613	0.0451	25.4	27.7	1.412	1.295	0.92	132	18.8
0:45			54.8								145	
1:00	610	28	55.4								148	
1:15			62.5	0.1571	0.0489	23.4	25.5	2.671	2.446	0.92	152	35.5
1:30	305	28	68.8								156	
1:45			68.7								158	
2:00	605	28	70.6	0.1589	0.0500	24.6	25.0	2.875	2.825	0.98	159	38.3
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			77.1								172	
2:30	305	28	79.3								174	
2:45			83.0	0.1619	0.0501	26.6	24.9	3.124	3.329	1.07	179	41.6
3:00	605	28	85.7	0.1620	0.0507	26.7	24.6	3.214	3.480	1.08	187	42.8
3:15			85.4								189	
3:30	300	28	85.4								187	
3:45			88.0	0.1628	0.0506	27.3	24.7	3.227	3.565	1.10	189	42.9
4:00	600	28	91.9	0.1624	0.0509	27.1	24.5	3.395	3.743	1.10	191	45.2
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			95.4								192	
4:30	300	28	100.1								192	
4:45			100.0	0.1634	0.0505	27.7	24.7	3.608	4.040	1.12	190	48.0
5:00	600	30	102.1	0.1645	0.0498	28.5	25.1	3.482	4.071	1.14	190	48.0
5:15			107.2								198	
5:30	300	30	106.9								202	
5:45			108.7	0.1667	0.0479	30.1	26.1	3.617	4.170	1.15	198	48.1
6:00	600	30	105.9	0.1649	0.0495	28.8	25.2	3.646	4.165	1.15	198	48.5
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			105.0								197	
6:30	305	30	109.7								198	
6:45			116.0	0.1675	0.0463	30.5	27.0	3.798	4.301	1.13	196	50.5
7:00	605	30	115.5	0.1670	0.0470	30.2	26.6	3.694	4.186	1.13	195	51.0
7:15			114.0								195	
7:30	300	30	114.0								194	
7:45			115.5	0.1670	0.0468	30.1	26.7	3.838	4.325	1.13	194	51.1
8:00	600	32	114.5	0.1670	0.0467	30.1	26.7	3.703	4.167	1.13	192	51.1

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			114.5								194	
8:30	300	30	114.0								193	
8:45			113.7	0.1654	0.0460	28.9	27.2	3.858	4.068	1.12	191	51.3
9:00	600	30	114.8	0.1663	0.0455	29.3	27.4	3.815	4.072	1.12	191	51.8
9:15			114.0								190	
9:30	300	32	114.1								190	
9:45			114.5	0.1660	0.0460	29.1	27.2	3.924	4.204	1.10	190	52.2
10:00	600	32	113.9	0.1648	0.0484	28.5	25.8	3.969	4.384	1.10	190	52.5

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			116.0								191	
10:30	290	32	117.1								191	
10:45			117.1	0.1657	0.0460	28.6	25.4	3.974	4.312	1.12	191	52.9
11:00	565	32	118.6	0.1667	0.0455	29.6	27.5	4.010	4.320	1.12	190	53.3
11:15			116.3								189	
11:30	250	32	116.2	0.1654	0.0461	27.9	26.6	3.678	3.826	1.12	190	51.1

Total Test time (min:sec)	11:30
Total Number of Revolutions	6,840
Maximum Workload (Kp)	2.75
Average Stroke Rate (stks·min^{-1})	30
Total Power Output (Kpm)	14,284
$\dot{V}O_2$ max (L·min^{-1})	4.010
$\dot{V}O_2$ max ml^{-1}·Kg^{-1}·min^{-1}	53.3
Maximum Heart Rate (bts·min^{-1})	202
AT % of $\dot{V}O_2$ max (L·min^{-1})	84%
Time at AT	4:00
Workload at AT	1.75
Revolutions at AT	2,420
Power Output at AT	3,932
$\dot{V}O_2$ L·min^{-1} at AT	3.395
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	45.2
Heart Rate at AT	177

Table A4

Post-Training Test Raw Data of Subject 2

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			35.5	0.1601	0.0474	25.5	26.3	1.421	1.348	0.95	124	18.8
0:30	310	26	48.1	0.1586	0.0480	24.1	26.1	1.997	1.848	0.93	136	26.4
0:45			47.9								138	
1:00	610	26	50.0								140	
1:15			64.1	0.1545	0.0514	22.3	24.3	2.879	2.640	0.92	144	38.1
1:30	305	26	64.3								144	
1:45			62.7								144	
2:00	605	26	69.5	0.1562	0.0527	23.3	23.7	2.987	2.932	0.98	145	39.5
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			68.2								150	
2:30	310	26	71.1								151	
2:45			73.4	0.1577	0.0529	24.2	23.6	3.037	3.112	1.02	153	40.1
3:00	610	26	79.0									
3:15			78.0									
3:30	300	27	83.0	0.1595	0.0528	25.3	23.6	3.284	3.512	1.07	157	43.4
3:45			77.7	0.1579	0.0543	24.5	23.0	3.175	3.384	1.07	155	42.0
4:00	600	27	85.0								161	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			86.9								164	
4:30	300	27	90.6	0.1602	0.0529	25.8	23.6	3.512	3.841	1.09	164	46.4
4:45			92.9	0.1604	0.0532	26.0	23.5	3.576	3.956	1.11	164	47.3
5:00	600	27	83.4								167	
5:15			97.3								168	
5:30	295	27	92.6	0.1605	0.0526	25.0	23.7	3.567	3.902	1.09	169	47.1
5:45			94.2	0.1606	0.0528	26.0	23.7	3.620	3.979	1.10	170	47.8
6:00	595	27	92.5								172	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			99.9								174	
6:30	300	27	103.0	0.1633	0.0504	27.6	24.8	3.727	4.155	1.12	176	49.3
6:45			93.5	0.1608	0.0527	26.1	23.7	3.578	3.944	1.10	176	47.3
7:00	595	27	104.0								177	
7:15			95.1								178	
7:30	300	27	100.7	0.1614	0.0521	26.5	24.0	3.802	4.201	1.10	178	50.3
7:45			102.2	0.1622	0.0516	27.0	24.2	3.787	4.220	1.11	178	50.1
8:00	600	27	106.2								179	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			107.8								179	
8:30	290	28	104.8	0.1632	0.0504	27.6	24.8	3.796	4.229	1.11	179	50.2
8:45			106.7	0.1640	0.0495	28.0	25.2	3.805	4.226	1.11	180	50.3
9:00	590	28	107.0								180	
9:15			111.6								180	
9:30	300	28	113.2	0.1648	0.0484	28.5	25.8	3.969	4.384	1.10	180	52.5
9:45			111.0	0.1649	0.0483	28.5	25.8	3.889	4.295	1.10	182	51.4
10:00	600	29	105.1	0.1669	0.0470	30.1	26.6	3.491	3.954	1.13	180	46.1

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			109.9	0.1640	0.0488	27.9	25.6	3.941	4.292	1.09	182	52.1
10:30	305	29	108.7								180	
10:45			96.7								180	
11:00	595	30	104.9	0.1622	0.0494	26.6	25.3	3.936	4.147	1.05	180	52.0
11:15			108.8								181	
11:30	300	30	103.8								181	
11:45			108.7	0.1643	0.0496	28.3	25.2	3.841	4.312	1.12	181	50.8
12:00	600	31	103.9	0.1617	0.0491	26.2	25.4	3.954	4.081	1.03	181	52.3

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			101.6	0.1602	0.0435	24.3	28.5	4.184	4.569	1.09	182	52.5
12:30	300	31	99.4	0.1592	0.0441	23.7	28.1	4.187	4.543	1.08	184	52.2
12:45											185	
13:00	590	32									186	
13:15			102.4	0.1602	0.0428	24.2	28.9	4.236	4.541	1.07	186	52.8
13:30	290	32	109.3	0.1605	0.0422	24.4	29.0	4.487	5.071	1.13	189	56.0
13:45			119.7	0.1605	0.0422	24.3	29.3	4.929	5.183	1.05	190	61.5
14:00	565	32	106.8								192	

Total Test time (min:sec)	14:00
Total Number of Revolutions	8,370
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	18,037
Average Stroke Rate ($stks \cdot min^{-1}$)	28
$\dot{V}O_2$ max ($L \cdot min^{-1}$)	4.929
$\dot{V}O_2$ max $m \cdot Kg^{-1} \cdot min^{-1}$	61.5
Maximum Heart Rate ($bts \cdot min^{-1}$)	198
AT % of $\dot{V}O_2$ max ($L \cdot min^{-1}$)	80.5%
Time at AT	9:30
Workload at AT	2.50
Revolutions at AT	6,005
Power Output at AT	10,535
$\dot{V}O_2$ $L \cdot min^{-1}$ at AT	3.969
$\dot{V}O_2$ $ml \cdot Kg^{-1} \cdot min^{-1}$ at AT	52.5
Heart Rate at AT	180

Table A5

Pre-Training Test Raw Data of Subject 3

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	O_2 ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			30.1								120	
0:30	315	26	40.2	0.1679	0.0411	29.9	30.4	1.346	1.321	0.98	121	17.9
0:45			48.2								124	
1:00	625	26	48.0								127	
1:15			53.0	0.1562	0.0449	22.4	27.8	2.362	1.904	0.81	130	31.4
1:30	310	27	54.3								132	
1:45			59.0								134	
2:00	620	27	65.6	0.1578	0.0466	23.5	26.8	2.793	2.448	0.88	137	37.2
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			64.6								141	
2:30	305	27	66.1								144	
2:45			70.2	0.1584	0.0479	24.0	26.1	2.925	2.692	0.92	146	38.9
3:00	610	27	71.4								147	
3:15			77.0								148	
3:30	305	27	75.8	0.1615	0.0474	25.9	26.4	2.929	2.872	0.98	149	39.0
3:45			79.1								151	
4:00	605	27	74.2								154	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			81.7	0.1632	0.0455	26.8	27.5	3.047	2.973	0.98	156	40.5
4:30	305	27	82.1	0.1646	0.0450	27.7	27.8	2.958	2.953	1.00	158	39.4
4:45			84.9								160	
5:00	610	28	87.3								160	
5:15			86.4	0.1627	0.0478	26.8	26.1	3.220	3.306	1.03	161	42.8
5:30	300	28	90.2								161	
5:45			89.9								162	
6:00	600	28	94.9	0.1669	0.0441	29.5	28.4	3.215	3.348	1.04	162	42.8
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			101.3	0.1676	0.0444	30.2	28.2	3.355	3.594	1.07	163	44.6
6:30	305	28	92.2								163	
6:45			101.1								164	
7:00	605	28	99.0	0.1670	0.0448	29.7	27.9	3.328	3.549	1.09	165	44.3
7:15			104.3	0.1673	0.0447	30.0	28.0	3.475	3.729	1.07	166	46.2
7:30	300	28	114.3								166	
7:45			108.0								168	
8:00	600	28	103.1	0.1691	0.0424	31.3	29.5	3.300	3.500	1.06	169	43.9

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			112.0	0.1693	0.0430	31.6	29.1	3.548	3.580	1.08	170	47.2
8:30	305	28	111.4								170	
8:45			115.3								171	
9:00	605	28	121.0	0.1702	0.0423	32.3	29.6	3.742	4.090	1.09	172	49.8
9:15			119.2	0.1706	0.0420	32.8	29.8	3.636	4.003	1.10	172	48.4
9:30	310	28	115.1								174	
9:45			119.6								174	
10:00	610	28	124.9	0.1709	0.0421	33.1	29.7	3.776	4.198	1.11	175	50.2

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			134.1	0.1722	0.0411	34.3	30.4	3.905	4.407	1.13	175	52.0
10:30	300	29	130.5								177	
10:45			138.9								178	
11:00	600	29	131.5	0.1725	0.0410	34.7	30.5	3.790	4.310	1.14	179	50.4
11:15			130.3	0.1730	0.0400	35.1	31.2	3.715	4.170	1.12	180	49.4
11:30	300	29	138.2								182	
11:45			153.7	0.1747	0.0389	37.0	32.2	4.158	4.775	1.15	182	55.3
12:00	600	29	160.1	0.1759	0.0385	38.6	32.5	4.143	4.923	1.19	184	55.1

WORKLOAD 7, 3:00 Kp, changed at 12:00 minutes

12:15			166.3	0.1762	0.0383	39.0	32.7	4.265	5.092	1.19	185	56.7
12:30	300	31	165.6	0.1757	0.0395	38.6	31.7	4.285	5.227	1.22	185	57.0
12:45			173.9	0.1755	0.0399	38.5	31.4	4.513	5.544	1.23	186	60.0
13:00	600	31	179.6	0.1771	0.0384	40.6	32.6	4.429	5.515	1.25	186	58.9
13:15			171.9	0.1766	0.0384	39.7	32.6	4.328	5.282	1.22	187	57.6
13:30	305	32	178.7								188	
13:45			183.3	0.1779	0.0365	41.3	34.3	4.441	5.346	1.20	189	59.1
14:00	600	32	182.5	0.1773	0.0373	40.5	33.6	4.508	5.432	1.20	189	60.0

Total Test time (min:sec)	14:00
Total Number of Revolutions	8,490
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	18,962
Average Stroke Rate (stks·min^{-1})	28
$\dot{V}O_2$ max (L·min^{-1})	4.513
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	60.0
Maximum Heart Rate (bts·min^{-1})	189
AT % of $\dot{V}O_2$ max (L·min^{-1})	74.3%
Time at AT	6:15
Workload at AT	2.25
Revolutions at AT	3,670
Power Output at AT	6,662
$\dot{V}O_2$ L·min^{-1} at AT	3.355
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	44.6
Heart Rate at AT	163

Table A6

Post-Training Test Raw Data of Subject 3

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			40.2	0.1736	0.0375	35.1	33.2	1.145	1.210	1.06	123	14.5
0:30	305	26	46.5	0.1649	0.0391	26.9	31.9	1.725	1.458	0.85	123	21.8
0:45			45.0	0.1591	0.0401	23.4	31.1	1.926	1.450	0.75	108	24.3
1:00	605	26	52.7								119	
1:15			61.9	0.1566	0.0446	22.5	27.9	2.748	2.219	0.81	128	34.7
1:30	310	26	68.2								129	
1:45			66.5								130	
2:00	610	26	63.4	0.1587	0.0454	23.8	27.4	2.665	2.310	0.87	130	33.7
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			70.7								130	
2:30	305	26	63.8								131	
2:45			69.6	0.1607	0.0444	24.9	28.0	2.799	2.483	0.89	132	35.4
3:00	605	26	69.4								135	
3:15			72.0								136	
3:30	310	26	77.1	0.1611	0.0450	25.2	27.7	3.062	2.787	0.91	138	38.7
3:45			80.2	0.1619	0.0446	25.7	27.9	3.123	2.873	0.92	140	39.5
4:00	610	26	82.0								140	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			73.4								140	
4:30	300	27	80.6	0.1625	0.0442	26.0	28.2	3.101	2.861	0.92	140	39.2
4:45			82.8								141	
5:00	600	27	85.4								143	
5:15			87.5	0.1637	0.0425	26.6	29.3	3.289	2.987	0.91	145	
5:30	295	27	88.1								146	
5:45			86.3								146	
6:00	595	27	81.1	0.1649	0.0413	27.3	30.2	2.974	2.688	0.90	147	37.6
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			88.0								149	
6:30	300	27	93.2								151	
6:45			93.1	0.1643	0.0419	26.9	29.7	3.457	3.131	0.91	153	43.7
7:00	600	27	100.7	0.1657	0.0414	27.9	30.1	3.611	3.345	0.93	153	45.6
7:15			102.0								154	
7:30	295	27	101.6								154	
7:45			105.5	0.1657	0.0418	28.0	29.6	3.766	3.542	0.94	154	47.6
8:00	600	27	103.3	0.1667	0.0407	28.6	30.6	3.613	3.378	0.93	156	45.6

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			110.8								157	
8:30	300	27	114.2								157	
8:45			121.9	0.1683	0.0397	29.0	31.3	4.084	3.890	0.95	158	51.6
9:00	605	27	116.7	0.1684	0.0401	30.0	31.1	3.890	3.753	0.96	159	49.1
9:15			120.6								160	
9:30	300	27	122.5								160	
9:45			127.2	0.1697	0.0386	30.9	32.2	4.111	3.939	0.96	161	51.9
10:00	600	27	130.2	0.1694	0.0389	30.8	32.0	4.239	4.096	0.96	163	53.5

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			134.6	0.1699	0.0383	31.1	32.5	4.327	4.134	0.96	164	54.7
10:30	305	28	139.3								167	
10:45			136.9	0.1702	0.0385	31.4	32.4	4.356	4.226	0.97	168	55.0
11:00	605	28	134.9	0.1702	0.0383	31.4	32.5	4.297	4.150	0.97	167	54.3
11:15			146.3	0.1719	0.0383	33.2	32.7	4.409	4.473	1.01	169	55.7
11:30	305	28	140.7								170	
11:45			145.1	0.1710	0.0379	32.2	32.9	4.512	4.407	0.98	170	57.0
12:00	605	28	151.2	0.1727	0.0366	33.7	34.1	4.484	4.436	0.99	169	56.6

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			147.4	0.1729	0.0369	34.0	33.8	4.332	4.365	1.01	165	54.7
12:30	300	30	153.3	0.1706	0.0372	31.6	33.5	4.278	4.041	0.94	166	54.0
12:45			144.4	0.1717	0.0362	32.5	34.4	4.442	4.196	0.94	167	56.1
13:00	600	30	148.1								168	
13:15			146.7								169	
13:30	305	30	153.9	0.1730	0.0358	33.8	34.8	4.553	4.420	0.97	170	57.5
13:45			161.5	0.1733	0.0358	34.8	34.8	4.714	4.642	0.98	171	59.5
14:00	605	30	155.8								171	

WORKLOAD 8, 3.50 Kp, changed at 14:00 minutes

14.15			165.5	0.1736	0.0353	34.4	35.3	4.807	4.685	0.97	173	60.7
14:30	305	32	164.9	0.1737	0.0352	34.5	35.4	4.774	4.658	0.98	175	60.3
14:45			164.3	0.1735	0.0358	34.4	35.0	4.811	4.718	0.98	176	60.8
15:00	605	32	169.5	0.1732	0.0364	34.2	34.2	4.951	4.951	1.00	176	62.5
15:15			168.6	0.1733	0.0365	34.4	34.2	4.901	4.938	1.01	177	61.9
15:30	305	33	172.2	0.1733	0.0362	34.3	34.4	5.016	5.004	1.00	178	63.4
15:45			183.0								181	
16:00	610	34	186.4	0.1753	0.0348	36.5	35.8	5.111	5.198	1.02	182	64.6

WORKLOAD 9, 3.75 Kp, changed at 16:00 minutes

16:15			183.5	0.1746	0.0355	35.8	35.1	5.122	5.228	1.02	183	64.7
16:30	305	34	184.9	0.1746	0.0353	35.7	35.3	5.184	5.235	1.01	183	65.5
16:45			190.4	0.1752	0.0350	36.5	35.6	5.222	5.348	1.02	184	66.0
17:00	605	34	192.3	0.1751	0.0355	36.5	35.2	5.270	5.471	1.04	184	66.6
17:15			183.2	0.1748	0.0365	36.3	34.1	5.042	5.367	1.06	185	63.7
17:30	305	35	188.5	0.1748	0.0355	36.1	35.1	5.228	5.372	1.03	185	66.0
17:45			194.1	0.1756	0.0352	37.1	35.4	5.237	5.483	1.05	186	66.2
18:00	610	36	190.3	0.1753	0.0355	36.7	35.2	5.182	5.411	1.04	182	65.5

Total Test time (min:sec)	18:00
Total Number of Revolutions	10,880
Maximum Workload (Kp)	3.75
Total Power Output (Kpm)	23,247
Average Stroke Rate (stks·min^{-1})	29
$\dot{V}O_2$ max (L·min^{-1})	5.270
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	66.6
Maximum Heart Rate (bts·min^{-1})	186
AT % of $\dot{V}O_2$ max (L·min^{-1})	82.1%
Time at AT	10:15
Workload at AT	2.75
Revolutions at AT	6,030
Power Output at AT	12,052
$\dot{V}O_2$ L·min^{-1} at AT	4.327
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	54.7
Heart Rate at AT	163

Table A7

Pre-Training Test Raw Data of Subject 4

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ /ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			29.0	0.1644	0.0395	27.1	32.0	1.071	0.906	0.85	126	17.4
0:30	310	28	35.6	0.1551	0.0417	21.8	30.4	1.632	1.173	0.72	136	26.4
0:45			46.8								140	
1:00	610	28	49.6								145	
1:15			52.2	0.1537	0.0469	21.6	27.0	2.413	1.936	0.80	165	39.1
1:30	305	28	59.2								170	
1:45			59.2								172	
2:00	610	28	68.6	0.1592	0.0451	24.4	28.0	2.810	2.445	0.87	178	45.6
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			61.6								182	
2:30	305	28	71.5								185	
2:45			74.4	0.1599	0.0460	24.9	27.5	2.987	2.709	0.91	188	48.5
3:00	605	29	78.4								190	
3:15			77.8								195	
3:30	300	29	79.3	0.1607	0.0464	25.5	27.3	3.111	2.909	0.94	198	50.5
3:45			82.7								198	
4:00	605	29	82.7								201	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			80.4	0.1608	0.0469	25.6	27.0	3.140	2.983	0.95	207	51.0
4:30	300	29	77.3	0.1598	0.0476	25.1	26.6	3.079	2.906	0.94	206	50.0
4:45			85.6								204	
5:00	600	29	88.9								204	
5:15			88.7	0.1624	0.0461	26.6	27.4	3.330	3.233	0.97	205	54.0
5:30	300	30	90.3	0.1624	0.0461	26.6	27.4	3.393	3.293	0.97	210	55.1
5:45			89.1								210	
6:00	600	30	91.5								204	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			88.1	0.1617	0.0465	26.2	27.2	3.359	3.328	0.96	204	54.5
6:30	300	31	85.6	0.1610	0.0475	25.9	26.6	3.306	3.214	0.97	204	53.6
6:45			95.6	0.1601	0.0484	25.4	26.1	3.770	3.658	0.97	205	61.2
7:00	600	30	91.6	0.1615	0.0479	26.3	26.4	3.547	3.529	0.99	209	57.6
7:15			93.2								209	
7:30	300	31	97.8	0.1629	0.0470	27.1	26.9	3.603	3.634	1.01	211	58.5
7:45			97.3								211	
8:00	600	31	90.5								210	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			104.0	0.1640	0.0464	27.9	27.2	3.730	3.817	1.02	210	60.5
8:30	300	31	104.4	0.1648	0.0459	28.4	27.6	3.682	3.789	1.03	210	59.7
8:45			101.9								210	
9:00	600	32	107.0								210	
9:15			104.0	0.1643	0.0464	28.1	27.2	3.701	3.819	1.03	210	610
9:30	300	32	99.2	0.1632	0.0467	27.3	27.1	3.631	3.663	1.01	210	58.9
9:45			106.0								212	
10:00	595	32									212	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			104.5	0.1640	0.0458	27.8	27.6	3.761	3.789	1.01	215	61.0
10:30	305	32	108.0	0.1651	0.0449	28.5	28.2	3.797	3.832	1.01	215	61.6
10:45			108.5	0.1661	0.0441	29.1	28.7	3.723	3.784	1.02	214	60.4
11:00	525	32	109.0	0.1665	0.0438	29.5	28.9	3.696	3.773	1.02	213	60.0

Total Test time (min:sec)	11:00
Total Number of Revolutions	6,550
Maximum Workload (Kp)	2.75
Total Power Output (Kpm)	14,319
Average Stroke Rate (stks·min^{-1})	30
$\dot{V}O_2$ max (L·min^{-1})	3.797
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	61.6
Maximum Heart Rate (bts·min^{-1})	215
AT % of $\dot{V}O_2$ max (L·min^{-1})	86.8%
Time at AT	5:15
Workload at AT	2.00
Revolutions at AT	3,030
Power Output at AT	3,948
$\dot{V}O_2$ L·min^{-1} at AT	3.330
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	54.0
Heart Rate at AT	202

Table A8

Post-Training Test Raw Data of Subject 4

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			34.9	0.1667	0.0428	29.1	29.2	1.199	1.193	1.00	166	18.8
0:30	300	26	42.0	0.1576	0.0440	23.1	28.4	1.820	1.477	0.81	171	28.6
0:45			47.6								168	
1:00	600	26	52.9								175	
1:15			59.5	0.1547	0.0468	21.9	26.7	2.717	2.225	0.82	174	42.7
1:30	300	26	51.2								172	
1:45			63.8								180	
2:00	600	26	59.9	0.1548	0.0491	22.1	25.5	2.705	2.354	0.87	181	42.5
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			65.7								184	
2:30	300	26	67.3								185	
2:45			65.1	0.1563	0.0494	23.0	25.3	2.833	2.575	0.91	184	44.5
3:00	600	26	68.4								188	
3:15			71.4								190	
3:30	295	26	77.6	0.1580	0.0493	23.9	25.3	3.245	3.064	0.94	192	51.0
3:45			76.2	0.1584	0.0493	24.2	25.3	3.155	3.008	0.95	192	49.6
4:00	595	26	75.7								192	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			78.4								192	
4:30	300	27	75.8	0.1571	0.0508	23.6	24.6	3.212	3.083	0.96	194	50.5
4:45			80.1								194	
5:00	600	27	82.6								194	
5:15			78.9	0.1517	0.0517	23.5	24.2	3.359	3.264	0.97	195	52.8
5:30	300	27	86.1	0.1594	0.0502	24.9	24.9	3.458	3.461	1.00	196	54.3
5:45			89.6								196	
6:00	600	27	88.0								198	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			94.2	0.1622	0.0484	26.5	25.8	3.556	3.648	1.03	200	55.9
6:30	300	27	89.4	0.1609	0.0495	25.8	25.2	3.467	3.542	1.02	200	54.5
6:45			95.7								200	
7:00	600	27	97.2								200	
7:15			96.4	0.1626	0.0478	26.7	26.1	3.606	3.687	1.02	201	56.7
7:30	295	27	98.1	0.1629	0.0479	27.0	26.1	3.637	3.763	1.03	201	57.2
7:45			95.8								202	
8:00	580	27	105.5								202	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			104.7	0.1636	0.0477	27.5	26.2	3.813	3.995	1.05	203	59.9
8:30	300	27	104.3	0.1626	0.0492	26.9	25.4	3.869	4.104	1.06	204	60.8
8:45			99.4	0.1600	0.0522	25.6	23.9	3.889	4.153	1.07	205	61.1
9:00	600	27	110.7								205	
9:15			109.8	0.1646	0.0476	28.2	26.3	3.893	4.181	1.07	205	61.2
9:30	300	27	108.6	0.1649	0.0472	28.4	26.4	3.828	4.106	1.07	205	60.2
9:45			107.5								206	
10:00	600	27	114.2								206	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			111.0	0.1659	0.0458	29.0	27.3	3.825	4.070	1.06	208	60.1
10:30	300	27	105.9								209	
10:45			110.7								209	
11:00	600	27	112.7	0.1638	0.0476	27.6	26.2	4.086	4.297	1.05	208	64.2
11:15			113.6	0.1662	0.0455	29.2	27.5	3.891	4.139	1.06	209	61.9
11:30	300	27	113.3	0.1662	0.0459	29.3	27.5	3.871	4.156	1.07	198	60.8
11:45			115.3								210	
12:00	600	27	112.2								210	

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			119.9	0.1674	0.0445	30.1	28.1	3.986	4.265	1.07	212	62.6
12:30	280	31	118.6								212	
12:45			118.9								212	
13:00	505	31	116.6	0.1685	0.0437	30.9	28.6	3.774	4.072	1.08	214	59.6

Total Test time (min:sec)	13:00
Total Number of Revolutions	7,670
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	17,602
Average Stroke Rate (stks·min^{-1})	29
$\dot{V}O_2$ max (L·min^{-1})	4.086
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	64.2
Maximum Heart Rate (bts·min^{-1})	214
AT % of $\dot{V}O_2$ max (L·min^{-1})	88.8%
Time at AT	8:15
Workload at AT	2.50
Revolutions at AT	4,775
Power Output at AT	9,322
$\dot{V}O_2$ L·min^{-1} at AT	3.813
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	59.9
Heart Rate at AT	203

Table A9

Pre-Training Test Raw Data of Subject 5

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD	1,	1.50 Kp								
0:15			26.1	0.1607	0.0458	25.0	27.2	1.044	0.961	0.92	122	13.5
0:30	335	27	27.3	0.1557	0.0481	22.4	25.8	1.217	1.055	0.87	118	15.8
0:45			25.7								136	
1:00	665	27	38.4								138	
1:15			42.5	0.1620	0.0451	25.8	27.6	1.651	1.542	0.93	149	
1:30	310	28	54.2								159	
1:45			57.6								164	
2:00	620	28	69.8	0.1576	0.0487	23.5	25.5	2.969	2.734	0.92	166	38.5
		WORKLOAD	2,	1.75 Kp,	changed at 2:00 minutes							
2:15			71.3								167	
2:30	305	29	69.2								167	
2:45			78.0	0.1564	0.0542	23.5	22.9	3.323	3.401	1.02	169	43.1
3:00	620	29	77.5								170	
3:15			87.3								170	
3:30	310	30	84.5	0.1592	0.0543	25.2	22.9	3.357	3.689	1.10	171	43.5
3.45			89.0	0.1594	0.0546	25.4	22.8	3.506	3.912	1.12	174	45.4
4:00	620	30	89.5								176	
		WORKLOAD	3,	2.00 Kp,	changed at 4:00 minutes							
4:15			84.3								176	
4:30	310	30	89.9	0.1589	0.0553	25.1	22.5	3.577	4.003	1.12	176	46.4
4:45			96.5	0.1617	0.0526	26.7	23.6	3.620	4.083	1.13	178	46.9
5:00	620	30	104.5								179	
5:15			95.4								179	
5:30	310	30	107.5	0.1630	0.0517	27.5	24.1	3.906	4.467	1.14	180	50.6
5.45			108.9	0.1645	0.0488	28.2	25.5	3.862	4.274	1.11	182	52.2
6:00	615	30	111.9								184	
		WORKLOAD	4,	2.25 Kp,	changed at 6:00 minutes							
6:15			118.1								184	
6:30	305	30	114.8	0.1651	0.0477	28.5	26.1	4.028	4.397	1.09	186	52.2
6:45			119.7	0.1665	0.0467	29.6	26.6	4.048	4.492	1.11	186	52.5
7:00	625	30	114.7								188	
7:15			120.0								188	
7:30	305	29	127.6	0.1670	0.0462	29.9	27.0	4.272	4.731	1.11	188	55.4
7:45			120.8	0.1666	0.0458	29.5	27.2	4.101	4.449	1.08	190	53.2
8:00	615	30	125.3								191	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			126.2	0.1688	0.0432	31.0	28.9	4.071	4.375	1.07	192	52.8
8:30	310	30	136.5	0.1694	0.0429	31.5	29.0	4.328	4.700	1.09	193	56.1
8:45			125.4	0.1669	0.0446	29.6	27.9	4.243	4.495	1.06	195	55.0
9:00	620	30	131.4	0.1681	0.0436	30.4	28.5	4.323	4.605	1.07	195	56.0
9:15			140.7	0.1691	0.0424	31.1	29.4	4.516	4.789	1.06	195	58.5
9:30	330	28	156.1	0.1691	0.0429	31.3	29.0	4.990	5.377	1.08	195	64.7
9:45			156.3	0.1700	0.0439	32.3	28.4	4.833	5.508	1.14	196	62.6
10:00	640	28	159.4	0.1698	0.0442	32.2	28.2	4.948	5.664	1.14	196	64.1

Total Test time (min:sec)	10:00
Total Number of Revolutions	6,260
Maximum Workload (Kp)	2.50
Total Power Output (Kpm)	12,486
Average Stroke Rate (stks·min^{-1})	29
$\dot{V}O_2$ max (L·min^{-1})	4.990
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	64.7
Maximum Heart Rate (bts·min^{-1})	196
AT % of $\dot{V}O_2$ max (L·min^{-1})	78.2%
Time at AT	5:30
Workload at AT	2.00
Revolutions at AT	3,145
Power Output at AT	5,338
$\dot{V}O_2$ L·min^{-1} at AT	3.906
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	50.6
Heart Rate at AT	180

Table A10

Post-Training Test Raw Data of Subject 5

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			30.8	0.1567	0.0471	22.9	26.6	1.344	1.160	0.86	146	17.9
0:30	325	27	40.6	0.1486	0.0508	19.6	24.6	2.351	1.873	0.80	148	31.3
0:45			46.3								149	
1:00	630	27	52.6								151	
1:15			53.8	0.1456	0.0578	19.0	21.6	2.829	2.493	0.88	151	37.6
1:30	305	27	62.9								155	
1:45			59.2								156	
2:00	610	27	62.2	0.1493	0.0576	20.5	21.7	3.041	2.870	0.94	158	40.5
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			73.5								159	
2:30	310	27	68.7								160	
2:45			69.2	0.1490	0.0595	20.5	21.0	3.376	3.300	0.98	162	44.9
3:00	610	27	76.6	0.1517	0.0579	21.6	21.5	3.554	3.555	1.00	162	47.3
3:15			75.4								164	
3:30	305	27	61.2								165	
3:45			82.6	0.1532	0.0575	22.3	21.7	3.710	3.806	1.03	166	49.4
4:00	610	27	80.1	0.1528	0.0583	22.1	21.4	3.617	3.743	1.03	167	48.1
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			81.0								169	
4:30	305	27	77.2								169	
4:45			86.5	0.1539	0.0574	22.6	21.8	3.832	3.974	1.04	170	51.0
5:00	605	27	71.0	0.1497	0.0614	21.0	20.3	3.382	3.492	1.03	171	45.0
5:15			77.9								172	
5:30	310	27	86.0								173	
5:45			76.2	0.1518	0.0586	21.7	21.3	3.516	3.582	1.02	174	46.8
6:00	610	27	87.0								174	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			85.4								180	
6:30	300	27	88.1	0.1536	0.0574	22.4	21.8	3.924	4.048	1.03	183	52.2
6:45			96.3								183	
7:00	605	27	88.8								183	
7:15			101.1	0.1556	0.0570	23.5	21.9	4.305	4.611	1.07	184	57.3
7:30	300	27	94.6	0.1558	0.0564	23.5	22.1	4.017	4.273	1.06	185	53.4
7:45			92.0								186	
8:00	600	27	99.7								187	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			99.6	0.1572	0.0555	24.2	22.5	4.111	4.429	1.08	188	54.7
8:30	310	28	100.7	0.1561	0.0572	23.8	21.8	4.239	4.611	1.09	188	56.4
8:45			106.0	0.1534	0.0592	22.5	21.1	4.702	5.031	1.07	189	62.6
9:00	615	28	101.3								190	
9:15			110.3	0.1585	0.0545	24.9	22.9	4.433	4.817	1.09	190	59.0
9:30	305	29	97.8	0.1571	0.0564	24.3	22.1	4.034	4.423	1.10	189	53.7
9:45			109.9								190	
10:00	610	29	110.0								190	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			110.1	0.1586	0.0551	25.0	22.7	4.400	4.856	1.10	192	58.5
10:30	300	29	109.4	0.1596	0.0542	25.6	23.0	4.280	4.751	1.11	195	57.0
10:45			115.4								194	
11:00	600	29	119.8								195	
11:15			127.5	0.1615	0.0527	26.6	23.7	4.790	5.378	1.12	196	63.7
11:30	305	30	121.2	0.1611	0.0531	26.4	23.5	4.589	5.158	1.12	197	61.1
11:45			124.4								197	
12:00	605	29	127.1								198	

WORKLOAD 7, 3:00 Kp, changed at 12:00 minutes

12:15			137.6	0.1633	0.0507	27.7	24.7	4.972	5.583	1.12	199	66.2
12:30	315	30	131.2	0.1633	0.0511	27.8	24.4	4.729	5.371	1.14	202	62.9
12:45			143.9	0.1633	0.0496	27.6	25.2	5.221	5.717	1.09	203	69.5
13:00	625	30	147.2									
13:15			130.1									
13:30	310	30	148.8	0.1654	0.0503	29.4	24.8	5.065	5.997	1.18	203	67.4
13:45			156.9	0.1668	0.0491	30.4	25.4	5.157	6.170	1.20	203	68.6
14:00	615	30	147.7	0.1650	0.0546	29.8	22.9	4.948	6.461	1.31	203	65.8

Total Test time (min:sec)	14:00
Total Number of Revolutions	8,550
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	19,219
Average Stroke Rate (stks·min^{-1})	28
$\dot{V}O_2$ max (L·min^{-1})	5.221
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	69.5
Maximum Heart Rate (bts·min^{-1})	203
AT % of $\dot{V}O_2$ max (L·min^{-1})	81.2%
Time at AT	8:30
Workload at AT	2.50
Revolutions at AT	5,190
Power Output at AT	9,526
$\dot{V}O_2$ L·min^{-1} at AT	4.239
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	56.4
Heart Rate at AT	188

Table A11

Pre-Training Test Raw Data of Subject 6

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			34.8	0.1719	0.0400	34.1	31.6	1.019	1.100	1.08	147	11.2
0:30	305	27	50.7	0.1610	0.0439	25.4	28.8	1.998	1.757	0.88	144	21.9
0:45			54.0								146	
1:00	605	27	66.5								146	
1:15			70.4	0.1556	0.0510	23.1	24.8	3.052	2.845	0.93	148	33.5
1:30	305	27	78.3								149	
1:45			74.7								149	
2:00	610	27	82.5	0.1588	0.0514	25.0	24.6	3.308	3.356	1.01	150	36.3
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			76.4	0.1573	0.0538	24.3	23.5	3.140	3.258	1.04	154	34.4
2:30	310	28	82.4								154	
2:45			75.9								156	
3:00	610	28	86.6	0.1579	0.0532	24.6	23.8	3.515	3.643	1.04	157	38.5
3:15			82.9	0.1579	0.0528	25.1	23.9	3.303	3.463	1.05	158	36.2
3:30	300	28	86.6								158	
3:45			84.1								160	
4:00	600	29	86.8	0.1594	0.0527	25.5	24.0	3.403	3.625	1.07	162	37.3
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			77.3	0.1575	0.0537	24.4	23.5	3,162	3.283	1.04	164	34.7
4:30	300	29	96.7								165	
4:45			92.3								168	
5:00	605	29	90.0	0.1601	0.0505	25.7	25.0	3.503	3.597	1.03	169	38.4
5:15			100.4	0.1624	0.0499	27.2	25.3	3.689	3.968	1.08	170	40.5
5:30	295	30	99.8								170	
5:45			96.6								172	
6:00	595	30	102.9	0.1628	0.0485	27.3	26.0	3.775	3.953	1.05	173	41.4
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			103.4	0.1627	0.0491	27.3	25.7	3.787	4.019	1.06	174	41.5
6:30	300	30	103.6	0.1586	0.0531	25.0	23.8	4.137	4.359	1.05	175	45.5
6:45			106.8								176	
7:00	600	30	101.8	0.1624	0.0490	27.1	25.8	3.748	3.948	1.05	176	41.2
7:15			109.2	0.1627	0.0488	27.2	25.9	4.010	4.222	1.05	177	44.0
7:30	300	30	94.8								179	
7:45			113.6								180	
8:00	600	30	110.9	0.1635	0.0476	27.7	26.6	4.004	4.171	1.04	181	43.9

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			118.6	0.1648	0.0471	28.6	26.8	4.144	4.423	1.07	181	45.4
8:30	300	30	112.8	0.1610	0.0514	26.4	24.6	4.272	4.594	1.08	182	46.6
8:45			110.2								183	
9:00	600	30	112.6	0.1638	0.0471	27.8	26.9	4.045	4.191	1.04	183	44.4
9.15			123.3	0.1656	0.0460	29.1	27.5	4.240	4.486	1.06	184	46.5
9:30	295	31	117.8								184	
9:45			117.1								185	
10:00	600	31	125.0	0.1657	0.0448	29.0	28.2	4.311	4.425	1.03	186	47.3

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			122.2								186	
10:30	300	31	119.7								187	
10:45			118.0	0.1642	0.0459	27.9	27.6	4.226	4.280	1.01	187	46.3
11:00	600	31	128.9	0.1659	0.0450	29.2	28.1	4.416	4.588	1.04	188	48.4
11:15			118.8	0.1633	0.0474	27.5	26.7	4.326	4.458	1.03	189	47.4
11:30	300	31	113.9								189	
11:45			128.2	0.1654	0.0451	28.8	28.1	4.452	4.569	1.03	190	48.8
12:00	600	31	118.8	0.1653	0.0450	29.6	28.1	4.146	4.230	1.02	190	45.5

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			132.5								192	
12:30	295	32	122.5								192	
12:45			110.0	0.1613	0.0496	26.4	25.5	4.171	4.316	1.03	193	45.7
13:00	595	32	122.7	0.1652	0.0443	28.5	28.5	4.304	4.300	1.00	195	47.2
13:15			141.3	0.1661	0.0438	29.1	28.9	4.917	4.959	1.01	195	53.9
13:30	285	32	140.9								196	
13:45			130.5	0.1658	0.0455	29.2	27.8	4.472	4.700	1.05	197	49.0
14:00	460	32	139.3	0.1669	0.0445	30.0	28.4	4.650	4.901	1.05	198	51.0

Total Test time (min:sec)	14:00
Total Number of Revolutions	8,280
Maximum Workload (Kp)	3.00
Total Power Output (Kpm)	18,505
Average Stroke Rate ($stks \cdot min^{-1}$)	29
$\dot{V}O_2$ max ($L \cdot min^{-1}$)	4.917
$\dot{V}O_2$ max $ml \cdot Kg^{-1} \cdot min^{-1}$	53.9
Maximum Heart Rate ($bts \cdot min^{-1}$)	198
AT % of $\dot{V}O_2$ max ($L \cdot min^{-1}$)	76.7%
Time at AT	6:00
Workload at AT	2.00
Revolutions at AT	3,615
Power Output at AT	6,340
$\dot{V}O_2$ $L \cdot min^{-1}$ at AT	3.775
$\dot{V}O_2$ $ml \cdot Kg^{-1} \cdot min^{-1}$ at AT	41.4
Heart Rate at AT	173

Table A12

Post-Training Test Raw Data of Subject 6

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			35.6	0.1604	0.0453	24.9	27.6	1.432	1.291	0.90	127	16.1
0:30	305	25	44.4	0.1545	0.0486	22.0	25.7	2.021	1.727	0.85	130	22.7
0:45			44.5								131	
1:00	605	25	49.2								131	
1:15			49.9	0.1470	0.0525	19.1	23.8	2.611	2.097	0.80	132	
1:30	300	25	53.0								132	
1:45			58.7								136	
2:00	600	26	61.8	0.1505	0.0515	20.4	24.2	3.027	2.549	0.84	139	33.9
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			61.5								140	
2:30	300	26	65.0								140	
2:45			61.5	0.1501	0.0532	20.4	23.5	3.019	2.618	0.87	140	33.8
3:00	600	26	68.6								144	
3:15			67.7								146	
3:30	300	26	65.8	0.1494	0.0558	20.3	22.4	3.235	2.940	0.91	149	36.3
3:45			68.6								149	
4:00	600	26	73.7								150	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			70.3	0.1524	0.0541	21.5	23.1	3.269	3.043	0.93	152	36.6
4:30	300	26	84.3	0.1533	0.0539	21.9	23.2	3.844	3.693	0.95	154	43.1
4:45			84.9								156	
5:00	600	26	82.3								157	
5:15			83.6	0.1545	0.0532	22.4	23.5	3.726	3.559	0.96	158	41.8
5:30	295	26	89.8	0.1553	0.0532	22.9	23.5	3.931	3.831	0.97	163	44.1
5:45			90.9								164	
6:00	595	26	86.8								165	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			93.5	0.1556	0.0536	31.1	23.3	4.054	4.010	0.99	165	45.5
6:30	290	26	87.4	0.1548	0.0542	22.7	23.0	3.845	3.790	0.99	165	43.1
6:45			99.4								166	
7:00	590	26	92.9								167	
7:15			95.0	0.1561	0.0530	23.3	23.6	4.083	4.031	0.98	169	45.8
7:30	300	26	98.9	0.1566	0.0529	23.6	23.6	4.194	4.187	1.00	170	47.0
7:45			98.1								171	
8:00	600	26	104.7								172	

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			100.7	0.1567	0.0537	23.7	23.3	4.254	4.328	1.02	173	47.7
8:30	295	27	98.5	0.1572	0.0532	23.9	23.5	4.118	4.194	1.02	174	46.2
8:45			106.3								175	
9:00	595	27	100.5								175	
9:15			108.4	0.1580	0.0521	24.3	24.0	4.471	4.524	1.01	175	50.1
9:30	295	27	106.8	0.1582	0.0526	24.5	23.7	4.368	4.503	1.03	177	49.0
9:45			104.7								179	
10:00	600	27	119.8								178	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			110.3	0.1590	0.0515	24.8	24.2	4.450	4.549	1.02	178	49.9
10:30	300	27	115.6	0.1608	0.0505	25.8	24.7	4.476	4.673	1.04	178	50.2
10:45			109.8								179	
11:00	600	27	102.7								179	
11:15			115.6	0.1600	0.0516	25.5	24.2	4.535	4.776	1.05	180	50.8
11:30	295	27	117.0	0.1597	0.0519	25.3	24.1	4.623	4.860	1.05	181	51.8
11:45			106.2								181	
12:00	595	27	117.5								181	

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			117.8	0.1602	0.0515	25.6	24.2	4.610	4.858	1.05	182	51.7
12:30	300	27	123.5	0.1613	0.0506	26.2	24.7	4.720	4.998	1.06	182	52.9
12:45			118.7								182	
13:00	600	28	124.2								182	
13:15			127.2	0.1611	0.0509	26.1	24.5	4.868	5.187	1.07	183	54.6
13:30	300	28	123.5	0.1604	0.0518	25.7	24.1	4.798	5.121	1.07	184	53.8
13:45			127.1								184	
14:00	600	28	127.1								184	

WORKLOAD 8, 3.50 Kp, changed at 14:00 minutes

14:15			122.1	0.1592	0.0529	25.1	23.6	4.858	5.177	1.07	184	54.5
14:30	300	28	128.9	0.1608	0.0516	26.0	24.2	4.954	5.325	1.07	185	55.5
14:45			136.0								185	
15:00	600	28	135.2								185	
15:15			131.6	0.1612	0.0513	26.2	24.4	5.013	5.399	1.08	185	56.2
15:30	295	28	135.5	0.1625	0.0507	27.1	24.6	5.007	5.497	1.10	187	56.1
15:45			138.9								188	
16:00	405	28	127.7	0.1599	0.0531	25.6	23.5	4.906	5.347	1.01	188	55.0

Total Test time (min:sec)	16:00
Total Number of Revolutions	9,380
Maximum Workload (Kp)	3.50
Average Stroke Rate (stks·min^{-1})	27
Total Power Output (Kpm)	22,367
$\dot{V}O_2$ max (L·min^{-1})	5.013
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	56.2
Maximum Heart Rate (bts·min^{-1})	188
AT % of $\dot{V}O_2$ max (L·min^{-1})	89.2%
Time at AT	9:15
Workload at AT	2.50
Revolutions at AT	5,385
Power Output at AT	10,825
$\dot{V}O_2$ L·min^{-1} at AT	4.471
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	50.1
Heart Rate at AT	175

Table A13

Pre-Training Test Raw Data of Subject 7

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			41.7	0.1659	0.0432	28.2	28.7	1.479	1.455	0.98	116	16.6
0:30	320	27	39.1	0.1572	0.0457	22.8	27.1	1.712	1.443	0.84	117	19.2
0:45			55.1								123	
1:00	630	27	54.1								129	
1:15			64.0	0.1481	0.0516	19.2	24.0	3.324	2.668	0.80	129	37.2
1:30	310	27	69.6								130	
1:45			69.9								132	
2:00	620	27	71.6	0.1532	0.0514	21.4	24.1	3.348	2.975	0.89	132	37.5
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			70.8								131	
2:30	305	27	72.4								133	
2:45			71.4	0.1521	0.0532	21.1	23.2	3.372	3.061	0.91	136	37.8
3:00	610	27	71.4								139	
3:15			70.6								139	
3:30	310	27	70.7	0.1492	0.0549	20.0	22.5	3.438	3.051	0.89	138	38.5
3:45			75.5								139	
4:00	610	27	75.6								138	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			79.4	0.1513	0.0549	20.9	22.5	3.801	3.526	0.93	143	42.6
4:30	300	28	75.1								143	
4:45			80.4								143	
5:00	600	28	80.1	0.1530	0.0543	21.6	22.8	3.713	3.519	0.95	144	41.6
5.15			80.6								146	
5:30	300	28	81.5								147	
5:45			86.1	0.1544	0.0532	2.22	23.2	3.883	3.707	0.95	148	43.5
6:00	600	28	86.1								149	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			85.9								149	
6:30	305	28	84.9	0.1527	0.0549	21.5	22.5	3.911	3.738	0.96	150	43.8
6:45			82.8								149	
7:00	605	28	84.4								149	
7:15			87.3	0.1527	0.0543	21.4	22.8	4.071	3.836	0.94	150	45.6
7:30	300	29	90.8								152	
7:45			89.4								154	
8:00	600	29	90.7	0.1530	0.0547	21.7	22.6	4.189	4.011	0.96	154	46.9

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			92.1								155	
8:30	305	29	91.9								155	
8:45			88.3	0.1512	0.0564	21.0	21.9	4.168	3.988	0.96	156	46.7
9:00	605	29	88.9								156	
9:15			90.3								155	
9:30	300	29	91.2	0.1506	0.0584	20.9	21.2	4.367	4.309	0.99	157	48.9
9:45			95.7	0.1517	0.0572	21.3	21.6	4.495	4.424	0.98	158	50.3
10:00	600	29	96.1								158	

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			93.3								158	
10:30	300	30	90.9	0.1493	0.0596	20.4	20.7	4.453	4.380	0.98	157	49.9
10:45			96.2								159	
11:00	600	30	98.1								161	
11:15			103.7	0.1536	0.0565	21.1	21.9	4.681	4.741	1.01	164	52.4
11:30	305	30	106.8	0.1537	0.0563	22.3	21.9	4.820	4.870	1.01	163	54.0
11:45			104.8								165	
12:00	610	30	112.1								166	

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			107.7	0.1536	0.0567	22.1	21.8	4.861	4.936	1.02	166	54.4
12:30	300	30	116.9	0.1554	0.0550	22.9	22.5	5.110	5.196	1.02	168	57.2
12:45			113.3								168	
13:00	600	30	117.5								168	
13:15			117.3	0.1560	0.0553	23.3	22.3	5.040	5.252	1.04	169	56.4
13:30	300	30	122.0	0.1562	0.0548	23.3	22.5	5.232	5.413	1.04	170	58.6
13:34			121.2								171	
14:00	600	30	122.2								170	

WORKLOAD 8, 3.50 Kp, changed at 14:00 minutes

14:15			134.8	0.1579	0.0541	24.2	22.8	5.566	5.899	1.06	173	62.3
14:30	300	30	128.5	0.1569	0.0550	23.8	22.5	5.408	5.721	1.06	173	60.6
14:45			135.6								174	
15:00	600	30	140.8	0.1590	0.0531	24.8	23.3	5.678	6.043	1.06	175	63.6
15:15			143.8	0.1598	0.0525	25.2	23.6	5.709	6.103	1.07	175	63.9
15:30	300	30	147.0								176	
15:45			139.3	0.1588	0.0535	24.7	23.1	5.633	6.029	1.07	177	63.1
16:00	600	30	147.7	0.1593	0.0535	25.0	23.1	5.908	6.397	1.08	178	66.2

WORKLOAD 9, 3.75 Kp, changed at 16:00 minutes

16:15			149.2	0.1568	0.0557	23.7	22.2	6.287	6.718	1.07	178	70.4
16:30	300	30	158.0	0.1626	0.0495	26.7	25.0	5.916	6.320	1.07	178	66.3
16:45			163.2	0.1631	0.0492	27.1	25.2	6.032	6.487	1.08	179	67.6
17:00	590	30	167.9	0.1640	0.0475	27.5	26.0	6.118	6.449	1.05	180	68.5

Total Test time (min:sec)	17:00
Total Number of Revolutions	10,280
Maximum Workload (Kp)	3.75
Average Stroke Rate (stks·min^{-1})	29
Total Power Output (Kpm)	25,474
$\dot{V}O_2$ max (L·min^{-1})	6.287
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	70.4
Maximum Heart Rate (bts·min^{-1})	180
AT % of $\dot{V}O_2$ max (L·min^{-1})	81.3%
Time at AT	12:30
Workload at AT	3.00
Revolutions at AT	7,590
Power Output at AT	16,362
$\dot{V}O_2$ L·min^{-1} at AT	5.110
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	57.2
Heart Rate at AT	168

Table A14

Post-Training Test Raw Data of Subject 7

Time min:sec	Revs No/min	St. Rt/ min	$\dot{V}_E$ BTPS L/min	FEO_2	$FECO_2$	$\dot{V}_E$ O_2 L/L	$\dot{V}_E$ CO_2 L/L	$\dot{V}O_2$ STPD L/min	$\dot{V}CO_2$ STPD L/min	RER	Heart Rate Bts/min	$\dot{V}O_2$ ml/Kg /min
		WORKLOAD 1, 1.50 Kp										
0:15			28.7	0.1623	0.0355	25.0	35.7	1.147	0.805	0.70	110	13.0
0:30	315	26	33.4	0.1509	0.0403	19.9	31.4	1.680	1.062	0.63	122	19.0
0:45			55.1								128	
1:00	615	26	58.8								130	
1:15			67.0	0.1478	0.0462	19.1	27.3	3.499	2.450	0.70	130	39.6
1:30	305	27	65.7								131	
1:45			63.7								132	
2:00	605	27	63.9	0.1459	0.0500	18.7	25.3	3.414	2.527	0.74	134	38.6
		WORKLOAD 2, 1.75 Kp, changed at 2:00 minutes										
2:15			65.6								134	
2:30	300	27	57.8								135	
2:45			54.6	0.1397	0.0547	17.1	23.1	3.197	2.364	0.74	136	36.2
3:00	600	27	63.5								140	
3:15			58.9								140	
3:30	305	27	67.3	0.1452	0.0527	18.7	24.0	3.598	2.808	0.78	140	40.7
3:45			66.5								140	
4:00	605	27	65.7								141	
		WORKLOAD 3, 2.00 Kp, changed at 4:00 minutes										
4:15			66.0	0.1457	0.0534	18.9	23.6	3.487	2.793	0.80	142	39.4
4:30	300	27	69.1								144	
4:45			69.7								143	
5:00	600	27	67.5	0.1454	0.0533	18.8	23.7	3.591	2.848	0.79	143	40.6
5:15			68.1								146	
5:30	300	27	70.6								145	
5:45			70.2	0.1444	0.0554	18.6	22.8	3.775	3.084	0.82	145	42.7
6:00	600	27	74.7								144	
		WORKLOAD 4, 2.25 Kp, changed at 6:00 minutes										
6:15			76.3								145	
6:30	300	28	75.6	0.1462	0.0546	19.2	23.1	3.940	3.267	0.83	148	44.6
6:45			74.8								149	
7:00	600	28	81.2								151	
7:15			75.9	0.1460	0.0555	19.2	22.7	3.954	3.336	0.84	151	44.7
7:30	295	28	78.3								151	
7:45			78.8								152	
8:00	595	28	80.5	0.1450	0.0566	18.9	22.3	4.253	3.603	0.85	151	48.1

WORKLOAD 5, 2.50 Kp, changed at 8:00 minutes

8:15			80.9								152	
8:30	300	28	81.7								153	
8:45			87.7	0.1468	0.0560	19.5	22.6	4.487	3.888	0.87	154	50.8
9:00	600	28	87.4	0.1464	0.0564	19.4	22.4	4.499	3.905	0.87	156	50.9
9:15			85.3								157	
9:30	300	28	93.5								158	
9:45			96.6	0.1494	0.0541	20.4	23.4	4.732	4.137	0.87	159	53.5
10:00	605	28	98.9	0.1504	0.0532	20.8	23.8	4.759	4.162	0.87	159	53.8

WORKLOAD 6, 2.75 Kp, changed at 10:00 minutes

10:15			98.7								160	
10:30	300	28	97.6								160	
10:45			100.2	0.1505	0.0531	20.8	23.8	4.816	4.216	0.88	161	54.5
11:00	595	28	96.9	0.1488	0.0545	20.2	23.2	4.796	4.185	0.87	161	54.3
11:15			97.9								163	
11:30	305	28	101.3								165	
11:45			104.1	0.1501	0.0548	20.8	23.1	5.011	4.513	0.90	166	56.7
12:00	610	28	103.3	0.1501	0.0545	20.7	23.2	4.980	4.454	0.89	167	56.3

WORKLOAD 7, 3.00 Kp, changed at 12:00 minutes

12:15			106.0								167	
12:30	300	28	105.2								167	
12:45			107.6	0.1507	0.0541	21.0	23.3	5.130	4.609	0.90	168	58.0
13:00	600	28	112.4	0.1512	0.0532	21.1	23.7	5.326	4.737	0.89	168	60.3
13:15			108.6								170	
13:30	305	28	110.2								169	
13:45			112.3	0.1507	0.0547	21.0	23.1	5.338	4.869	0.91	169	60.4
14:00	605	28	118.6	0.1519	0.0537	21.5	23.5	5.518	5.041	0.91	171	62.4

WORKLOAD 8, 3.50 Kp, changed at 14:00 minutes

14:15			121.0								171	
14:30	305	28	128.1								173	
14:45			129.9	0.1541	0.0518	22.4	24.4	5.812	5.327	0.92	174	65.8
15:00	595	29	131.0	0.1539	0.0526	22.3	24.0	5.861	5.458	0.93	173	66.3
15:15			135.1								173	
15:30	305	29	130.9	0.1537	0.0535	22.3	23.6	5.864	5.542	0.95	176	66.3
15:45			136.5	0.1548	0.0529	22.8	23.9	5.982	5.720	0.96	175	67.7
16:00	615	29	136.8								176	

WORKLOAD 9, 3.75 Kp, changed at 16:00 minutes

16:15			145.6								176	
16:30	310	30	140.8	0.1560	0.0515	23.3	24.5	6.039	5.741	0.95	177	68.3
16:45			139.5	0.1548	0.0529	22.9	23.9	6.107	5.845	0.96	177	69.1
17:00	610	30	146.3								179	
17:15			146.7								178	
17:30	305	31	146.7	0.1565	0.0509	23.6	24.8	6.226	5.910	0.95	180	70.4
17:45			156.7	0.1573	0.0506	23.9	25.0	6.546	6.279	0.96	180	74.11
18:00	610	31	160.6								180	
18:15			170.2	0.1605	0.0476	25.6	26.5	6.658	6.413	0.96	181	75.3
18:30	310	31	171.7	0.1610	0.0477	25.9	26.5	6.637	6.485	0.98	182	75.1
18:45			166.7	0.1611	0.0478	25.9	26.4	6.425	6.305	0.98	183	72.7
19:00	615	32	169.3							1.03	183	

Total Test time (min:sec)	19:00
Total Number of Revolutions	11,480
Maximum Workload (Kp)	3.75
Average Stroke Rate (stks·min^{-1})	28
Total Power Output (Kpm)	29,627
$\dot{V}O_2$ max (L·min^{-1})	6.658
$\dot{V}O_2$ max ml·Kg^{-1}·min^{-1}	75.3
Maximum Heart Rate (bts·min^{-1})	183
AT % of $\dot{V}O_2$ max (L·min^{-1})	87.3%
Time at AT	14:45
Workload at AT	3.50
Revolutions at AT	8,740
Power Output at AT	22,138
$\dot{V}O_2$ L·min^{-1} at AT	5.812
$\dot{V}O_2$ ml·Kg^{-1}·min^{-1} at AT	65.8
Heart Rate at AT	174

APPENDIX B

TRAINING PROGRAMS

TRAINING PROGRAM OF SUBJECT 1

PERIOD: Week 1 to 2.

DAY 1:

a) 15 min warm-up

b) 40 min Steady State Rowing (St. St. R.)

  i Workload (WL.) 2.00 Kp

  ii Target Heart Rate (T.H.R.): 145-150 $bts \cdot min^{-1}$

  iii Stroke Rate (St. Rt.): 25-26 $Stks \cdot min^{-1}$

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 3x (5 x 40 Stks ON/20 Stks OFF)

  i WL.: 2.25 Kp

  ii T.H.R.: 175-180

  iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 20 min St. St. R

  i WL.: 2.00 Kp

  ii T.H.R.: 150

  iii St. Rt.: 26-27

c) 3 x 5 min ON/4 min OFF

  i WL.: 2.25 Kp

  ii T.H.R.: 165-170

  iii St. Rt.: 27-29

d) Warm-down & stretch

<u>PERIOD</u>: Week 3 to 4.

<u>DAY 1</u>:

a) 15 min Warm-up

b) 2x (5 x 2 min ON/ 2 min OFF)

8-10 min Light between sets

i WL.: 2.50 Kp

ii T.H.R.: 177-185

iii St. Rt.: 28-32

c) Warm down & Stretch

<u>DAY 2</u>:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 2.00 Kp

ii T.H.R.: 145-150

c) Warm down & Stretch

<u>DAY 3</u>:

a) 15 min Warm-up

b) 3 x 5 ON/8 min OFF

i WL.: 2.25 Kp

ii T.H.R.: 177-182

c) Warm down & Stretch

PERIOD: Week 5 to 6

DAY 1:
a) 15 min warm-up
b) 3 x 5 ON/10 min Light now
   i WL.: 2.25 Kp
   ii T.H.R.: 178-182
   iii St. Rt.: 28-30
c) Warm down & Stretch

DAY 2:
a) 15 min warm-up
b) PYRAMID
   2x (3 min, 2 min, 1 min, 2 min, 3 min) ON/15 min OFF
   i WL.: 2.25 Kp
   ii T.H.R. 180-185
   iii St. Rt. 29-31
c) Warm down & Stretch

DAY 3:
a) 15 min Warm-up
b) 30 min St. St. R.
   i WL.: 2.00 Kp
   ii T.H.R.: 145-150
   iii St. Rt.: 25-26
c) Warm down & Stretch

PERIOD: Week 7 to 8

DAY 1:
a) 15 min warm-up
b) 7 x 3 min ON/5 min OFF
   i WL.: 2.25
   ii T.H.R.: 175-180
   iii St. Rt.: 29-30
c) Warm down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 2.00 Kp
   ii T.H.R.: 145-150
   iii St. Rt.: 26-27
c) Warm down & Stretch

DAY 3:
a) 15 min Warm-up
b) 8x (3 min ON/4 min OFF)
   i WL.: 2.25 Kp
   ii T.H.R.: 178-182
   iii St. Rt.: 28-30
c) Warm down & Stretch

TRAINING PROGRAM OF SUBJECT 2

PERIOD: Week 1 to 2

DAY 1:
a) 15 min warm-up
b) 25 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 2:
a) 15 min Warm-up
b) 4 x 4 ON/6 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 185-190
   ii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

PERIOD: Week 3 to 4

DAY 1:

a) 15 min warm-up

b) 3 x 8 min ON/6 min OFF

i WL.: 1.75 Kp

ii T.H.R.: 168-175

iii St. Rt.: 27-29

c) Warm-Down & Stretch

DAY 2:

a) 15 min Warm-up

b) 4 x 6 min ON/6 min OFF

i WL.: 175 Kp

ii T.H.R.: 178-185

iii St. Rt.: 29-31

c) Warm-down & Stretch

DAY 3:

a) 15 min Warm-up

b) 30 min St. st. R.

i WL.: 1.75 Kp

ii T.H.R.: 168-172

iii St. Rt.: 26-27

c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:

a) 15 min warm-up

b) 5 x 2 min ON/3 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 180-190

iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 1.75 Kp

ii T.H.R.: 160-165

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 5 x 4 min ON/4 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 180-190

iii St. Rt.: 29-31

c) Warm-down & Stretch

PERIOD: 7 to 8

DAY 1:
a) 15 min warm-up
b) 6 x 3 ON/4 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 185-190
   iii St. Rt.: 30-32
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 9 x 2 min ON/3 min OFF
   i WL.: 2.25 Kp
   ii T.H.R.: 186-190
   iii St. Rt.: 30-32
c) Warm-down & Stretch

TRAINING PROGRAM OF SUBJECT 3

PERIOD: Week 1 to 2

DAY 1:
a) 15 min warm-up
b) 8 x 2 min ON/2 min OFF
i WL.: 2.50 Kp
ii T.H.R.: 168-175
iiSt.Rt.: 27-29
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
i WL.: 2.00 Kp
ii T.H.R.: 152-156
iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 4 x 5 min ON/5 min OFF
i WL.: 2.75
ii T.H.R.: 175-178
iii St. Rt.: 28-30

PERIOD: Week 3 to 4

DAY 1:

a) 15 min warm-up

b) 7 x 3 ON/3 min OFF

i WL.: 2.50 Kp

ii T.H.R.:175-180

iii St. Rt.: 28-30

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 2.00 Kp

ii T.H.R.: 152-156

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) PYRAMID

2x (2 min ON, 2 min OFF, 3 min ON, 3 min OFF, 4 min ON, 4 min OFF, 3 min ON, 3 min OFF, 2 min ON, 2 min OFF 10-12 min Light Rowing

i LD.: 2.50 Kp

ii T.H.R.: 175-180

iii St. Rt.: 3032

c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:

a) 15 min warm-up

b) 7 x 3 min ON/5 min Light Rowing

i WL.: 2.50 Kp

ii T.H.R.: 175-185

iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 2.00 Kp

ii T.H.R.: 152-156

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 10 x 2 min ON/3.5 min OFF

i WL.: 2.75 Kp

ii T.H.R.: 178-185

iii St. Rt.: 31-33

c) Warm-down & Stretch

PERIOD: Week 7 to 8

DAY 1:

a) 15 min warm-up

b) 4 x 5 ON/5 min OFF

i WL.: 2.50

ii T.H.R.: 174-180

iii St. Rt.: 29-31

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 2.25 Kp

iiT.H.R.: 152-156

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 3 x 8 min ON/6 min OFF

i WL.: 2.50 Kp

ii T.H.R.: 178-186

iii St. Rt.: 29-30

c) Warm-down & Stretch

TRAINING PROGRAM OF SUBJECT 4

PERIOD: Week 1 to 2

DAY 1:
a) 15 min Warm-up
b) 25 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 2:
a) 15 min Warm-up
b) 4 x 4 ON/6 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 185-190
   ii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 3:
a) 15 min Warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

PERIOD: Week 3 to 4

DAY 1:
a) 15 min warm-up
b) 3 x 8 min ON/6 min OFF
   i WL.: 1.75 Kp
   ii T.H.R.: 168-175
   iii St. Rt.: 27-29
c) Warm-Down & Stretch

DAY 2:
a) 15 min warm-up
b) 4 x 6 min ON/6 min OFF
   i WL.: 175 Kp
   ii T.H.R.: 178-185
   iii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 30 min St. st. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 168-172
   iii St. Rt.: 26-27
c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:

a) 15 min warm-up

b) 5 x 2 min ON/3 min OFF

- i WL.: 2.00 Kp
- ii T.H.R.: 180-190
- iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

- i WL.: 1.75 Kp
- ii T.H.R.: 160-165
- iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 5 x 4 min ON/4 min OFF

- i WL.: 2.00 Kp
- ii T.H.R.: 180-190
- iii St. Rt.: 29-31

c) Warm-down & Stretch

PERIOD: 7 to 8

DAY 1:

a) 15 min warm-up

b) 6 x 3 ON/4 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 185-190

iii St. Rt.: 3032

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 1.75 Kp

ii T.H.R.: 165-170

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 9 x 2 min ON/3 min OFF

i WL.: 2.25 Kp

ii T.H.R.: 186-190

iii St. Rt.: 30-32

c) Warm-down & Stretch

TRAINING PROGRAM OF SUBJECT 5

PERIOD: Week 1 to 2

DAY 1:
a) 15 min warm-up
b) 25 min St. St. R.
i WL.: 1.75 Kp
ii T.H.R.: 165-170
iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 4 x 4 ON/6 min OFF
i WL.: 2.00 Kp
ii T.H.R.: 185-190
ii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 30 min St. St. R.
i WL.: 1.75 Kp
ii T.H.R.: 165-170
iii St. Rt.: 26-27
c) Warm-down & Stretch

PERIOD: Week 3 to 4

DAY 1:

a) 15 min warm-up

b) 3 x 8 min ON/6 min OFF

  i WL.: 1.75 Kp

  ii T.H.R.: 168-175

  iii St. Rt.: 27-29

c) Warm-Down & Stretch

DAY 2:

a) 15 min warm-up

b) 4 x 6 min ON/6 min OFF

  i WL.: 175 Kp

  ii T.H.R.: 178-185

  iii St. Rt.: 29-31

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 30 min St. st. R.

  i WL.: 1.75 Kp

  ii T.H.R.: 168-172

  iii St. Rt.: 26-27

c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:

a) 15 min warm-up

b) 5 x 2 min ON/3 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 180-190

iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 1.75 Kp

ii T.H.R.: 160-165

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 5 x 4 min ON/4 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 180-190

iii St. Rt.: 29-31

c) Warm-down & Stretch

PERIOD: 7 to 8

DAY 1:

a) 15 min warm-up

b) 6 x 3 ON/4 min OFF

i WL.: 2.00 Kp

ii T.H.R.: 185-190

iii St. Rt.: 30-32

c) Warm-down & Stretch

DAY 2:

a) 15 min warm-up

b) 30 min St. St. R.

i WL.: 1.75 Kp

ii T.H.R.: 165-170

iii St. Rt.: 26-27

c) Warm-down & Stretch

DAY 3:

a) 15 min warm-up

b) 9 x 2 min ON/3 min OFF

i WL.: 2.25 Kp

ii T.H.R.: 186-190

iii St. Rt.: 30-32

c) Warm-down & Stretch

TRAINING PROGRAM OF SUBJECT 6

PERIOD: Week 1 to 2

DAY 1:
a) 15 min Warm-up
b) 25 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 2:
a) 15 min Warm-up
b) 4 x 4 ON/6 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 185-190
   ii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 3:
a) 15 min Warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

<u>PERIOD</u>: Week 3 to 4

<u>DAY 1</u>:

a) 15 min Warm-up

b) 3 x 6 min ON/6 min OFF

i WL.: 1.75 Kp

ii T.H.R.: 168-175

iii St. Rt.: 27-29

c) Warm-Down & Stretch

<u>DAY 2</u>:

a) 15 min Warm-up

b) 4 x 6 min ON/6 min OFF

i WL.: 175 Kp

ii T.H.R.: 178-185

iii St. Rt.: 29-31

c) Warm-down & Stretch

<u>DAY 3</u>:

a) 15 min Warm-up

b) 30 min St. st. R.

i WL.: 1.75 Kp

ii T.H.R.: 168-172

iii St. Rt.: 26-27

c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:
a) 15 min warm-up
b) 5 x 2 min ON/3 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 180-190
   iii St. Rt.: 30-32
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 160-165
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 5 x 4 min ON/4 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 180-190
   iii St. Rt.: 29-31
c) Warm-down & Stretch

PERIOD: Week 7 to 8

DAY 1:
a) 15 min warm-up
b) 6 x 3 ON/4 min OFF
   i WL.: 2.00 Kp
   ii T.H.R.: 185-190
   iii St. Rt.: 3032
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 1.75 Kp
   ii T.H.R.: 165-170
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 9 x 2 min ON/3 min OFF
   i WL.: 2.25 Kp
   ii T.H.R.: 186-190
   iii St. Rt.: 30-32
c) Warm-down & Stretch

TRAINING PROGRAM OF SUBJECT 7

PERIOD: Week 1 to 2

DAY 1:
- a) 15 min warm-up
- b) 8 x 2 min ON/2 min OFF
  - i WL.: 3.00 Kp
  - ii T.H.R.: 168-175
  - iiSt.Rt.: 27-29
- c) Warm-down & Stretch

DAY 2:
- a) 15 min warm-up
- b) 30 min St. St. R.
  - i WL.: 2.50 Kp
  - ii T.H.R.: 152-156
  - iii St. Rt.: 26-27
- c) Warm-down & Stretch

DAY 3:
- a) 15 min warm-up
- b) 4 x 5 min ON/5 min OFF
  - i WL.: 2.75
  - ii T.H.R.: 175-178
  - iii St. Rt.: 28-30
- c) Warm-down & Stretch

PERIOD: Week 3 to 4

DAY 1:
a) 15 min warm-up
b) 7 x 3 ON/3 min OFF
   i WL.: 2.75 Kp
   ii T.H.R.: 175-180
   iii St. Rt.: 28-30
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 2.50 Kp
   ii T.H.R.: 152-156
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) PYRAMID
   2x (2 min ON, 2 min OFF, 3 min ON, 3 min OFF, 4 min ON, 4 min OFF, 3 min ON, 3 min OFF, 2 min ON, 2 min OFF 10-12 min Light Rowing
   i LD.: 2.75 Kp
   ii T.H.R.: 175-180
   iii St. Rt.: 30-32
c) Warm-down & Stretch

PERIOD: Week 5 to 6

DAY 1:
a) 15 min warm-up
b) 7 x 3 min ON/5 min Light Rowing
   i WL.: 3.25
   ii T.H.R.: 175-185
   iii St. Rt.: 30-32
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
   i WL.: 2.50 Kp
   ii T.H.R.: 152-156
   iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 10 x 2 min ON/3.5 min OFF
   i WL.: 3.50 Kp
   ii T.H.R.: 178-185
   iii St. Rt.: 31-33
c) Warm-down & Stretch

PERIOD: Week 7 to 8

DAY 1:
a) 15 min warm-up
b) 4 x 5 ON/5 min OFF
  i WL.: 3.00 Kp
  ii T.H.R.: 174-180
  iii St. Rt.: 29-31
c) Warm-down & Stretch

DAY 2:
a) 15 min warm-up
b) 30 min St. St. R.
  i WL.: 2.50 Kp
  iiT.H.R.: 152-156
  iii St. Rt.: 26-27
c) Warm-down & Stretch

DAY 3:
a) 15 min warm-up
b) 3 x 8 min ON/6 min OFF
  i WL.: 3.25 Kp
  ii T.H.R.: 178-186
  iii St. Rt.: 29-30
c) Warm-down & Stretch