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RELATIONSHIP OF THE ANAEROBIC THRESHOLD AND RUNNING PERFORMANCE IN FEMALE RECREATIONAL RUNNERS

by

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APPROVAL PAGE

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The purpose of the present study was to assess the relationship between anaerobic threshold values and performance times on the 5 km and 10 km distance races in female recreational runners. Anaerobic threshold (AT), $\dot{V}O_2$ max, and related measures were determined for 31 runners aged 18-35 who were running between 15-30 miles per week at the onset of the study. Physiological measures were determined by subjecting the runners to maximal and submaximal treadmill exercise. Determination of AT was based upon respiratory gas exchange and was defined as the departure from linearity of $\dot{V}_E\dot{V}O_2$ without a corresponding increase in $\dot{V}_E\dot{V}CO_2$. Mean AT-$\dot{V}O_2$ was 34.98 $ml \cdot kg \cdot min^{-1}$ (1.978 $l \cdot min^{-1}$) while $\dot{V}O_2$ max averaged 45.42 $ml \cdot kg \cdot min^{-1}$ (2.556 $l \cdot min^{-1}$). Mean percentage of AT-$\dot{V}O_2$ was 78.8%. Average treadmill velocity at AT was 152.53 m/min. The correlations between $\dot{V}O_2$ max and 10 km and 5 km performances were significant ($r = -.67$ and $-.58$, respectively) while those between AT-$\dot{V}O_2$ and running performances were not significant. However, when demographic characteristics of subjects were adjusted, treadmill velocity at AT and percentage of AT-$\dot{V}O_2$ were the best predictors of 10 km performance. Treadmill velocity at AT alone was the best predictor of 5 km performance when the effects of physical variables were partialed out. It was concluded that additional physiological parameters should be considered when attempting to predict 5 km and 10 km performance times for female recreational runners.

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A special thank-you is extended to my family who has continued to support, encourage, and believe in me. To Marshall, Lovie, and Boots, I dedicate this dissertation.

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CHAPTER I

INTRODUCTION

Maximal oxygen uptake has been designated as the best physiological predictor of cardiorespiratory fitness (Saltin & Astrand, 1967; Shepherd et al., 1968) and endurance performance (Costill, 1967; Costill, Thomason, & Roberts, 1973). However, there are limitations to the use of $\dot{V}O_2$ max as the sole measure of aerobic fitness. For example, $\dot{V}O_2$ max alone does not accurately predict running performance among individuals with similar aerobic capacities (Costill et al., 1973). Moreover, endurance athletes may continue to improve performance times without a concurrent increase in $\dot{V}O_2$ max (Astrand & Rodahl, 1977). Such observations imply that additional physiological mechanisms contribute to successful endurance performance. Factors such as body composition (Cureton & Sparling, 1980; Pollock et al., 1977), aging, heredity, and motivation (Katch, Sady, & Freedson, 1978) can have varying effects upon endurance performance. Prolonged exercise also appears to be affected to some degree by percentage of slow-twitch fibers (Costill, Fink, & Pollock, 1976), substrate utilization (Hermansen, Hultman, & Saltin, 1967), oxidative capacity (Farrell, Wilmore, Coyle, Billing, & Costill, 1979; Ivy, Costill, & Maxwell, 1980), running economy (Conley & Krahenbuhl, 1980; Costill & Winrow, 1970), and the ability to utilize a large percentage of $\dot{V}O_2$ max (Costill et al., 1973; Davies & Thompson, 1979).

Recent evidence has indicated that the anaerobic threshold (AT) is a good measure of submaximal fitness regardless of $\dot{V}O_2$ max (Weltman, Katch, Sady, & Freedson, 1978). In addition, AT is highly correlated with endurance performance (Farrell et al., 1979). Sjodin and Jacobs (1981) reported high correlations between marathon running and the treadmill velocity corresponding to the onset of metabolic acidosis.

Several investigators recently studied the accuracy with which AT predicted running performance. Thorland, Sady, and Refsell (1980) noted that the AT alone was a better predictor of running times than was $\dot{V}O_2$ max either singly or combined with the AT. Kumagai et al. (1982) revealed that AT values were better predictors of 5 km, 10 km, and 10-mile running performances among male runners than were $\dot{V}O_2$ max values.

There is a dearth of research that has focused on anaerobic threshold parameters of female subjects. The few investigations that were reported included samples of untrained women (Weltman et al., 1978), overfat women (Sady, Katch, Freedson & Weltman, 1980), trained athletes (Rusko, Rahkila, & Karvinen, 1980; Thorland et al., 1980), and more recently, recreational runners (Dwyer & Bybee, 1983; Londeree, Fay, LaFontaine, & Volek, 1984).

Statement of Problem

The primary purpose of the study was to determine and report the anaerobic threshold responses of female recreational runners subjected to maximal and submaximal treadmill exercise. A secondary purpose was to predict distance running success based on AT, treadmill velocity at AT, and $\dot{V}O_2$ max.

An appropriate treadmill protocol with which to assess the onset of AT had not been established at the onset of the study. A pilot study was designed and conducted to test the adequacy and reliability of a protocol incorporating a constant 0% grade and progressive speed increase.

Hypotheses

The following null hypotheses were tested:

1. There is no significant relationship between AT and running performance.

2. There is no significant relationship between AT and $\dot{V}O_2$ max.

3. There is no significant relationship between AT-$\dot{V}O_2$ and treadmill velocity.

Operational Definitions

1. Anaerobic threshold (AT) - a systematic increase in the ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}O_2$) without a corresponding increase in the ventilatory equivalent for CO_2 ($\dot{V}_E/\dot{V}CO_2$).

2. Anaerobic threshold oxygen consumption rate - the $\dot{V}O_2$ uptake corresponding to the treadmill velocity at which AT occurs (AT-$\dot{V}O_2$).

3. Carbon dioxide production - volume of CO_2 produced per minute, STPD ($\dot{V}CO_2$).

4. Five kilometer run - a pre-measured 3.1-mile course.

5. Fraction of expired carbon dioxide - percentage of CO_2 in expired air (FE_{CO_2}).

6. Fraction of expired oxygen - percentage of oxygen in expired air (FE_{O_2}).

7. Maximal oxygen uptake - the maximal rate at which oxygen can be consumed per minute ($\dot{V}O_2$ max).

8. Minute ventilation - amount of air expired in one minute, BTPS ($\dot{V}_E$).

9. Oxygen uptake - volume of oxygen consumed per minute, STPD ($\dot{V}O_2$).

10. Recreational runner - a female who runs between 15 and 30 miles per week.

11. Respiratory quotient - the ratio of the amount of carbon dioxide produced to the amount of oxygen consumed (R).

12. Ten kilometer run - a 6.2-mile road course.

13. Ventilatory equivalent for carbon dioxide - the amount of ventilation required per liter of CO_2 produced ($\dot{V}_E/\dot{V}CO_2$).

14. Ventilatory equivalent for oxygen - the amount of ventilation required per liter of oxygen consumed ($\dot{V}_E/\dot{V}O_2$).

Assumptions

1. Subjects exerted maximal efforts on the maximal treadmill test and distance runs.

2. The treadmill tests generated accurate anaerobic threshold and maximal oxygen uptake values.

3. Laboratory testing equipment was accurately calibrated.

Limitations

1. Times on distance runs may have been influenced by parameters other than AT and $\dot{V}O_2$ max.

2. Two 10 km courses were used in the study.

3. Many EKG recordings were not interpretable due to "noise" of instrumentation.

4. Several subjects failed to complete all four testing sessions due to scheduling problems and time restraints.

Significance of Study

The anaerobic threshold has recently been recognized as an important measure in exercise physiology. The quantification of the AT is essential to the examination of the ventilatory response to exercise (Davis, Frank, Whipp, & Wasserman, 1979) and is thought to be a major determinant of aerobic capacity (Costill et al., 1973).

Recently, the AT has received wide attention as a determinant of training intensity. In the past, physical training programs have been based largely on intensities corresponding to percentages of maximal heart rate or $\dot{V}O_2$ max. More recently, several investigators have prescribed training intensities relative to the AT (Davis et al., 1979; McLellan & Skinner, 1981; Sady et al., 1980). As Wasserman, Whipp, Koyal, and Beaver (1973) pointed out, heart rate cannot be used to identify the AT due to considerable within-subject variability. Katch et al. (1978) suggested that running speed associated with AT could be used as a training stimulus in the event that a high correlation exists between treadmill velocity and AT. There is evidence that such a relationship exists (Farrell et al., 1979; Sjodin & Jacobs, 1981). However, the majority of treadmill protocols utilized have been characterized by gradual increases in speed as well as grade. In order to prescribe exercise from treadmill velocity accurately, the grade must remain constant. Therefore, experimentation with such a protocol in the present study should add to the body of knowledge concerning the methodology in the measurement of the AT.

More descriptive data are needed regarding AT responses of female runners. Furthermore, the relationship between the AT and running performance in women runners needs further examination. To date, results of only three studies have been reported (Londeree et al., 1984; Tanaka, Matsuura & Moritani, 1981; Thorland et al., 1980). The AT was found to be a good predictor for the 5 km (Thorland et al., 1980; Tanaka, et al., 1981) and 10 km (Londeree et al., 1984) running events for female runners. Results of the present study should provide additional information regarding the relationship between women's middle- and long-distance running performance and AT responses.

CHAPTER II

REVIEW OF LITERATURE

The concept of the anaerobic threshold emerged from the work of Owles (1930) over 50 years ago. The investigator noted that during exercise, blood lactate did not increase until certain work intensities were exceeded. Once this threshold was surpassed, lactate was observed to rise exponentially (Hermansen & Stensvold, 1972; Saltin & Karlsson, 1971). Concomitant to the lactate response were increases in ventilation and carbon dioxide production. Recently, the term "anaerobic threshold" was applied to the exercise intensity above which arterial lactate rises (Davis, Vodak, Wilmore, Vodak, & Kurtz, 1976; Naimark, Wasserman, & McIlroy, 1964; Wasserman et al., 1973) and $\dot{V}_E$ and $\dot{V}CO_2$ increase nonlinearly with O_2 uptake (Skinner & McLellan, 1980; Wasserman, Van Kessel, & Burton, 1967; Wasserman et al., 1973). Additionally, several investigators demonstrated pronounced responses in $\dot{V}_E/\dot{V}O_2$ (Davis et al., 1979; Ready & Quinney, 1982), R (Wasserman et al., 1973), $PETO_2$ (Davis et al., 1979; Wasserman 1973), and excess CO_2 (Rhodes and McKenzie, 1984; Volkov, Shirkovets, & Borilkevich, 1975) during progressive increments in exercise intensity.

The workload corresponding to the AT varies among individuals. While the underlying mechanism of the AT remains controversial, factors such as work capacity and disease (Wasserman & Whipp, 1975), substrate utilization, regulation of glycolytic and oxidative enzymes, and muscle fiber recruitment (Skinner & McLellan, 1980) are possibly involved.

Concept of the Anaerobic Threshold

The noninvasive technique described by Naimark et al. (1964) and more recently by Wasserman et al. (1973) is a valid means of identifying the AT (Davis et al., 1976) due to the relationship between oxygen uptake, carbon dioxide and lactic acid production, and respiratory gas exchange (Weltman & Katch, 1979). If the circulation can adequately supply oxygen to the working muscles, aerobic metabolism can satisfy energy requirements. However, if the oxygen supply cannot meet the demand of the contracting muscle units, ATP can no longer be produced at the mitochondrial level. Energy production must then occur via the glycolytic pathway (Wasserman et al., 1973). Such a shift in metabolism occurs at an exercise intensity corresponding to 40-60% $\dot{V}O_2$ max (Skinner & McLellan, 1980). Consequently, lactic acid rises to twice resting values (2 $mmol \cdot l^{-1}$) (Wasserman et al., 1967; Wasserman et al., 1973; Whipp & Wasserman, 1972).

The acidity (H^+) produced by lactic acid during exercise is buffered by bicarbonate (HCO3), which prevents the dramatic pH change that ordinarily would occur with the appearance of such a strong acid (Wasserman, Whipp, & Davis, 1981). The buffering of the lactic acid consequential to increased anaerobiosis results in an increased production of CO_2 and a continuous rise in FE_{CO_2} (Wasserman et al., 1976; Skinner & McLellan, 1980). The additional CO_2, caused by the transfer of H^+ ions from muscle to plasma (Jones & Ehrsam, 1982) is excreted by the lungs and acts as a ventilatory stimulus (Wasserman et al., 1981). At low to moderate exercise, $\dot{V}_E$ is increased as a function of increased tidal volume in an attempt to offset the higher levels of CO_2 and lactic acid. At higher exercise intensities, V_E increases as a result of an increase in breathing frequency (Jones & Ehrsam, 1982). The rises in $\dot{V}_E$ and CO_2 result in an increase in $\dot{V}CO_2$ (Skinner & McLellan, 1980), while $\dot{V}O_2$ remains linear (Wasserman et al., 1981). As a result, disproportionate increases in $\dot{V}_E/\dot{V}O_2$ and R occur. Due to the buffering process, $\dot{V}_E/\dot{V}CO_2$ does not change (Wasserman et al., 1981).

Because the body consumes only enough oxygen needed to replenish ATP stores, the additional rise in $\dot{V}_E$ results in a lower extraction of oxygen per volume of ventilated air. Thus, an increase in FE_{O_2} is observed (Skinner & McLellan, 1980). To summarize, the occurrence of the AT described by Wasserman et al. (1973) is characterized by nonlinear increases in $\dot{V}_E$ and $\dot{V}CO_2$, an increase in FE_{O_2} without a concurrent decrease in FE_{CO_2}, and a rise in blood lactate from 2 $mmol \cdot l^{-1}$ (Skinner & McLellan, 1980).

The terminology assigned to the metabolic and respiratory responses to increasing exercise intensity appears controversial. The set of responses described by Wasserman et al. (1973) was labeled "aerobic threshold" by two investigators (Skinner & McLellan, 1980; McLellan & Skinner, 1981). The term "anaerobic threshold" was used to describe a second "breakaway" point in ventilation that occurs at exercise intensities corresponding to 65-90% $\dot{V}O_2$ max (Green, Daub, Painter, Houston & Thompson, 1979; MacDougall, 1977). The onset of this second phase of exercise is characterized by a sharp increase in lactic acid from 4 $mmol \cdot l^{-1}$, a decreased FE_{CO_2}, and pronounced hyperventilation (Skinner & McLellan, 1980).

Significance of the Anaerobic Threshold

The anaerobic threshold described by Wasserman et al. (1973) and Davis et al. (1979) has proved to be an instrumental concept in exercise physiology. In general, maximal oxygen uptake has been used to assess fitness and endurance performance by virtue of its strong correlations with heart volume, cardiac output, muscle capillarization, mitochondrial density, and oxidative enzyme capacity (Astrand & Rodahl, 1977). However, Wasserman et al. (1973) suggested that measurement of the AT allows a more complete analysis of the circulatory and metabolic adjustments to progressive exercise than is provided by measurement of $\dot{V}O_2$ max alone. In fact, the AT was recognized as the primary point of reference in the identification and interpretation of responses that occur during the transition from exercise of low to maximal intensity (Skinner & McLellan, 1980).

The AT is potentially useful in identifying optimal training intensities (Dwyer & Bybee, 1983; Katch et al., 1978). With few exceptions, training programs are designed such that the exercise intensity is based upon a percentage of maximal heart rate or $\dot{V}O_2$ max derived from exercise stress tests. Presently, exercise prescriptions associated with percentages of $\dot{V}O_2$ max or max HR do not distinguish between work performed above or below the AT (Katch et al., 1978). Thus, exercise performed at certain percentages of $\dot{V}O_2$ max may represent varying degrees of stress in individuals with similar maximal oxygen uptakes but dissimilar anaerobic thresholds.

Anaerobic threshold may also serve as a line of demarcation in terms of substrate utilization (Katch et al., 1978). In work performed below the AT, the primary fuel is fat (Newsholme, 1977). As exercise intensity increases, lipolysis is inhibited, and increased carbohydrate utilization occurs. Consequently, training at intensities above and below the AT should induce different training effects (Katch et al., 1978). Theoretically, training below the AT would result in body compositional changes. Cardiorespiratory adaptations would likely occur at exercise intensities above the AT (Katch et al., 1978).

The AT was shown to be a primary determinant of distance running performance (Wyndham, Strydom, & Van Rensburg, 1969). Costill (1970) reported that experienced runners performed at 70% of $\dot{V}O_2$ max before plasma lactate began to accumulate. It is also evident that the AT can be elevated through training despite a plateau in $\dot{V}O_2$ max (Davis et al., 1979; Sady et al., 1980; Williams, Wyndham, Kok, & von Rahden, 1967). By increasing the level of the AT via high intensity endurance interval training and long duration submaximal training (MacDougall, 1977), an athlete can potentially improve running performance.

Other uses of the anaerobic threshold were reported. AT served as an accurate predictor of running times in events ranging in distance from 5 km (Thorland et al., 1980; Kumagai et al., 1982) to the marathon (Rhodes & McKenzie, 1984). The AT also proved to be useful in clinical exercise testing in cardiac (Jones & Campbell, 1981; Powles, Sutton, Wicks, Oldridge, & Jones, 1979) and pulmonary disease (Jones, Jones, & Edwards, 1971).

Measurement of the Anaerobic Threshold

The noninvasive measurement of the anaerobic threshold gained recognition through the work of Wasserman et al. (1973). The investigators described the AT as the last linear value on the $\dot{V}_E$-workrate curve. Determination of the AT by ventilatory responses has become a reputable technique due to the accuracy with which such responses reflect metabolic acidosis. Davis et al. (1976) reported a strong relationship between the noninvasive method and the blood lactate technique (r=.95). More recently, Ponton, Tucker, Macy, and Sucec (1982) observed a higher association (r=.97). In contrast, Green, Hughson, Orr, and Ramey (1982) reported that AT determined by gas exchange variables occurred at a higher power output than did AT determined by blood lactate accumulation. Therefore, more formal comparisons of the two methods are needed, as suggested by Jones and Ehrsom (1982).

Determination of the AT via gas exchange variables is initiated by measurement of the ventilation, $\dot{V}O_2$, and $\dot{V}CO_2$ generated by incremental work bouts. No standard protocol for the measurement of AT has been established (Ready & Quinney, 1982). Jones and Campbell (1981) recommended a progressive incremental test which increases by 100 kpm/min (1.3 mph).

Although bicycle ergometer protocols were used in a majority of AT studies, treadmill protocols were utilized by several investigators (Kindermann, Simon, & Keul, 1979; Kumagai et al., 1982; Parkhouse, McKenzie, Rhodes, & Dunwoody, 1981; Priday, Knutzen, Lyon, & Moffatt, 1983; Rhodes & McKenzie, 1984). Increments in speed and/or grade ranged from 1-minute (Parkhouse et al., 1981; Powers, Dodd, Deason, Byrd, & McKnight, 1983; Rhodes & McKenzie, 1984) to 3.5-minute intervals (Kumagai et al., 1982). Wasserman et al. (1973) compared the metabolic and ventilatory responses resulting from 1- and 4-minute incremental bicycle ergometer tests. Similar respiratory measurements were observed with a greater increase in R in the 1-minute test. The investigators warned that increments occurring at less than 30-second intervals are likely to produce deceptively high AT values due to blood and tissue oxygen stores which could meet the energy requirements temporarily.

Two treadmill protocols entailed a 0% grade throughout testing. Speed increments were 13.41 m/min each minute (Rhodes & McKenzie, 1984) and every 3.5 minutes (Kumagai et al., 1982).

AT is commonly identified by plotting selected gas exchange variables by $\dot{V}O_2$ values ($l \cdot min^{-1}$) or time and denoting the break in linearity of expired ventilation and CO_2 (Wasserman et al., 1973). Alternate indices include (a) an increase in $\dot{V}_EO_2$ without a corresponding increase in $\dot{V}_ECO_2$, (b) an abrupt increase in FE_{O_2}, and (c) an increase in R (Davis et al., 1976; Wasserman et al., 1973). A less common method of identifying the AT is by examination of the CO_2 elimination curve defined as $(\dot{V}CO_2 - (RQ * \dot{V}O_2))$ (Volkov et al., 1975.). Rupp, Kanonchoff, Bartels, and Fox (1982) contended that the linearity departure of $\dot{V}_E$ is the best predictor of AT. R is the least sensitive measure (Davis et al., 1976).

Anaerobic threshold is generally determined by inspection of computer-printed graphs of selected gas exchange variables. Ventilatory parameters were measured continuously breath by breath (Davis et al., 1979; Wasserman et al., 1973) or at intervals ranging from 15 seconds

(Parkhouse et al., 1981; Rhodes & McKenzie, 1984) to 1 minute (Sady et al, 1980; Scheen, Juchmes, & Cession-Fossion, 1981; Weltman & Katch, 1979; Yoshida, Suda, & Takeuchi, 1982). The selected variables are then plotted as functions of $\dot{V}O_2$ (Dwyer & Bybee, 1983; LaFontaine, Londeree, & Spath, 1981; Powers et al., 1983), time (Davis et al., 1979; Whipp et al., 1973), or work rate (Kumagai et al., 1982; LaFontaine et al., 1981; Rhodes & McKenzie, 1984; Weltman et al., 1978).

The location of the AT is determined by fitting a straight line, by eye or computer, through each set of plotted data. Several investigators assessed the point of breakaway subjectively by visual inspection. In the event of a discrepancy, a third investigator served as arbitrator (Katch et al., 1978; Powers et al., 1983; Weltman et al., 1978). Computer techniques may be used to apply regression analysis to determine the location of the AT (Orr, Green, Hughson, & Bennett, 1980). Jones and Ehrsam (1982) noted that while the computer technique is more accurate, the criteria used in assessing the AT remain arbitrary.

A method for determining AT from six respiratory gas exchange parameters versus time was described by Davis et al. (1976). A vertical line was dropped from the departure of linearity of each criterion variable through the x-axis allowing an estimation for the AT. Times were then averaged, with the resultant mean time serving as the independent variable. Linear regression was used to determine the $\dot{V}O_2$ at the AT.

In summary, AT values may be measured directly by the blood lactate technique or noninvasively via selected gas exchange variables. Bicycle ergometer and treadmill protocols were used in the majority of studies. However, standardized protocols for the measurement of the AT have yet to be established.

Physiological Parameters of Trained and Untrained Subjects

Anaerobic Threshold Values. AT-$\dot{V}O_2$ values ranged from 13.31 $ml \cdot kg \cdot min^{-1}$ in overweight female subjects (Sady et al., 1980) to 45 $ml \cdot kg \cdot min^{-1}$ in highly trained female runners (Thorland et al., 1980). Mean values ranged from 44% in untrained subjects (Weltman et al., 1978) to 86% in trained cross-country skiers (Rusko et al., 1980) when expressed relative to $\dot{V}O_2$ max.

Only Dwyer and Bybee (1983) reported anaerobic threshold values for female recreational runners. The average AT value assessed during an incremental bicycle ergometer protocol was 27.0 $ml \cdot kg \cdot min^{-1}$ (1.56 $l \cdot min^{-1}$) corresponding to 70% max $\dot{V}O_2$. The range in percentage of $\dot{V}O_2$ max was 54-83%. The highest observed AT, relative to $\dot{V}O_2$ max was 1.78 $l \cdot min^{-1}$. The highest AT in absolute terms was 2.08 $l \cdot min^{-1}$ and corresponded to 79% $\dot{V}O_2$ max. Mean heart rate observed at the AT was 158.4 $b \cdot min^{-1}$, or 86.3% HR max.

Two studies were conducted on highly trained female athletes. Observed AT values were 40.9 $ml \cdot kg \cdot min^{-1}$, corresponding to 86% $\dot{V}O_2$ max in cross-country skiers (Rusko et al., 1980) and 45.0 $ml \cdot kg \cdot min^{-1}$ (80% $\dot{V}O_2$ max) in cross-country runners (Thorland et al., 1980).

Considerably more data are available on the AT values of male subjects. Average AT-$\dot{V}O_2$ ranged from 30.58 $ml \cdot kg \cdot min^{-1}$ in untrained male subjects (Weltman & Katch, 1978) to 52.4 $ml \cdot kg \cdot min^{-1}$ in trained distance runners (LaFontaine et al., 1981). A maximal AT-$\dot{V}O_2$ value of 57.7 $ml \cdot kg \cdot min^{-1}$ was reported in the latter study. Mean percent $\dot{V}O_2$ max values ranged from 46-60% in untrained male subjects (Weltman & Katch, 1978; Williams et al., 1967) and from 61-79% in highly trained male runners (Davies & Thompson, 1979; LaFontaine et al., 1981; Powers et al., 1983).

Maximal Oxygen Uptake Values. Maximal oxygen uptake values were reported for female collegiate physical education majors (Bransford & Howley, 1977), recreational runners (Dwyer & Bybee, 1983), trained collegiate runners (Bransford & Howley, 1977; Thorland et al., 1980), and elite runners (Daniels, Krahenbuhl, Foster, Gilbert, & Daniels, 1977; Wells, Hecht, & Krahenbuhl, 1981; Wilmore & Brown, 1974). Mean $\dot{V}O_2$ max values were 38.4 $ml \cdot kg \cdot min^{-1}$ for recreational runners (Dwyer & Bybee, 1983) and 44.2 $ml \cdot kg \cdot min^{-1}$ for physical education majors (Bransford & Howley, 1977). Mean values for the elite runners ranged from 53 $ml \cdot kg \cdot min^{-1}$ (Conley et al, 1981) to 59.6 $ml \cdot kg \cdot min^{-1}$ (Daniels et al, 1977).

Relationship Between Maximal Oxygen Uptake and Anaerobic Threshold. The relationship between $\dot{V}O_2$ max and AT ($l \cdot min^{-1}$) was reported in a number of studies. Correlations ranged from r=0.52 to 0.85 for male subjects (Davis et al., 1976; Davis et al., 1979; Weltman & Katch, 1979). Regression coefficients ranged from 0.69 in 33 untrained female subjects (Weltman et al., 1978) to 0.87 in 20 female recreational runners (Dwyer & Bybee, 1983). Such values indicate that although $\dot{V}O_2$

max and AT may reflect different components of running performance, the two measures are not entirely unrelated (Ready & Quinney, 1982).

Relationships Between Running Performance and Physiological Parameters.

Maximal oxygen uptake. Generally, $\dot{V}O_2$ max expressed relative to body weight ($ml \cdot kg \cdot min^{-1}$) has been the variable most closely associated with distance-running performance (Costill, 1972; Saltin & Astrand, 1967). However, correlations between $\dot{V}O_2$ max and distance running have ranged from r=-.12 (Conley & Krahenbuhl, 1980) to r=-.91 (Costill et al., 1973; Farrell et al., 1979). Such a range in correlations may be due to variations in running economy and $\dot{V}O_2$ max values among subjects across studies (Conley & Krahenbuhl, 1980) as well as variations in race distances (Farrell et al., 1979).

Several investigators examined the relationship between $\dot{V}O_2$ max and 5 km running performance. Thorland et al. (1980) reported a relationship of r= -.78 in a study of female cross-country runners. Correlations ranging from r = -.645 to r = -.85 were observed among male distance runners (Davies & Thompson, 1979; Farrell et al., 1979; Kumagai et al., 1982).

At the 10 km distance, conflicting results concerning the relationship between $\dot{V}O_2$ max and running performance were observed. A correlation of r = -.66 was reported by Conley, Krahenbuhl, Burkett, and Millar (1981) in the only reported investigation of female runners. In a study of male runners, Kumagai et al. (1982) found the relationship to be significant (r = -.753) when $\dot{V}O_2$ max was expressed in $l \cdot min^{-1}$ but nonsignificant when expressed relative to body weight. A stronger relationship (r = -.86) between $\dot{V}O_2$ max and running performance was observed by Farrell et al. (1979) at the slightly shorter 9.7 km distance. In contrast, Conley and Krahenbuhl (1980) reported an extremely low correlation ($r = -.12$) between $\dot{V}O_2$ max and 10 km performance of highly trained male distance runners. The investigators attributed such a low correlation to the greater homogeneity of subjects on $\dot{V}O_2$ max values and performance times as compared to subjects in other investigations.

Anaerobic threshold. The relationship between the AT and running performance has recently been a topic of increasing interest. Tanaka et al. (1981) noted that among middle- and long-distance runners, the AT-$\dot{V}O_2$ ($ml \cdot kg \cdot min^{-1}$) was the best physiological predictor of 3-mile running performance. The AT-$\dot{V}O_2$ alone accounted for 71% of the variance in men's 5 km performance (Kumagai et al., 1982).

Performance on the 10 km distance also appears to be closely related to AT-VO, at least among adolescent male distance runners (Kumagai et al., 1982) and adult male distance runners (Powers et al., 1983). It should be noted that the addition of $\dot{V}O_2$ max values (Kumagai et al., 1982; Powers et al., 1983; Thorland et al., 1980) and running economy (Powers et al., 1983) to prediction equations did not significantly improve multiple R values.

Kumagai et al., (1982) compared AT-$\dot{V}O_2$ and $\dot{V}O_2$ max values of good and poor runners based on 5 km, 10 km, and 10-mile performance times. Good runners demonstrated significantly higher AT-$\dot{V}O_2$ values than poor runners. However, no significant differences were shown in $\dot{V}O_2$ max values. Such findings suggest that distance-running success may be attributed to a higher AT-$\dot{V}O_2$.

Relationship Between Running Performance and Treadmill Velocity at AT

Recently, strong relationships were observed between running performance and the treadmill velocity associated with the onset of plasma lactate (OPLA) (Farrell et al., 1979; Rhodes & McKenzie, 1984; Sjodin & Jacobs, 1981). In several investigations of male distance runners, the treadmill velocity corresponding to OPLA was more closely related to running performance than was any other variable. Farrell et al. (1979) reported a correlation of r = 0.96 between treadmill velocity and 9.7 km performance. R values ranging from 0.96-0.98 were observed for marathon distances as well (Farrell et al., 1979; Sjodin & Jacobs, 1981).

Although there is little information on the relationship between treadmill velocity at OPLA and running performance for female runners, studies on male runners may be used for comparative purposes. In a group of male distance runners, the treadmill velocity corresponding to OPLA ranged from 168 to 303 m/min and averaged 236 m/min (Farrell et al., 1979). A slightly higher average treadmill velocity at OPLA of 258.9 m.min was observed by LaFontaine et al. (1981). Rhodes and McKenzie (1984) observed that AT in male marathon runners corresponded to a treadmill velocity of 247 m/min. At such a velocity, a correlation of r = .94 was established between predicted marathon time and actual running time.

Londeree et al. (1984) developed equations for estimating race pace for distances of 5 km, 10 km, and 10 miles in adult female collegiate and recreational runners. The investigators assigned the term "aerobic threshold" to the set of responses described by Davis et al. (1979) and "anaerobic threshold" to the second "breakaway" in expired ventilation. $\dot{V}O_2$ max and treadmill speed corresponding to the anaerobic threshold were the best predictors for 5 km performance (r = .97). Ten km and 10-mile performances were most closely related to $\dot{V}O_2$ max and treadmill speed corresponding to the aerobic threshold (r = .97).

It appears that the strong relationship between treadmill velocity at OPLA and distance running performance is evident among fast and slow runners as well. Farrell et al. (1979) reported that fastest and slowest marathoners performed at 7 and 3 m/min, respectively, above their OPLA velocities. Such an observation suggests that the relationship exists regardless of the runner's competitive status.

In summary, the treadmill velocity associated with the OPLA appears to be a good predictor of performance times for middle- and long-distance runners regardless of competitive status. There is evidence that such a velocity is more closely related to running performance than is any other variable.

CHAPTER III

METHODS

The following methods section is subdivided into pilot study methods and results, and procedures of the present investigation. Subject characteristics, testing sessions, treadmill protocol, determination of AT, and statistical analyses are discussed.

Pilot study

Four female physical education graduate students completed participation in a pilot study conducted during December of 1983. Such a study was designed to determine the test-retest reliability of the treadmill protocol in generating maximal oxygen uptake and AT values. Subjects were between 28 and 32 years of age and averaged 29.3 (± 1.89) years. Mean height and weight were 165.6 (± 4.22) cm and 66.6 (± 8.25) kg, respectively. All subjects were engaged in a regular jogging program at the onset of the study.

Two maximal treadmill tests based upon identical continuous incremental protocols were administered to each subject. A 0% grade was maintained for the duration of all tests. Initial treadmill speed was 3 mph (80.5 m/min) and increased 1 mph (26.8 m/min) every 2 minutes up to 5 mph (134.1 m/min). Thereafter, speed increased .5 mph (13.4 m/min) every 2 minutes.

$\dot{V}O_2$ max and AT-$\dot{V}O_2$ values generated by both treadmill tests were calculated by the methods described by Consolazio, Johnson, and Pecora (1963) and Wasserman et al. (1973) respectively. Mean $\dot{V}O_2$ max was 44.19 ($\pm$ 5.58) $ml \cdot kg \cdot min^{-1}$ on the first test and 44.15 ($\pm$ 4.86) $ml \cdot kg \cdot min^{-1}$ on the second. AT averaged 32.97 ($\pm$ 5.64) $ml \cdot kg \cdot min^{-1}$ and 33.40 ($\pm$ 5.61) $ml \cdot kg \cdot min^{-1}$ on the first and second tests, respectively. Individual data for each subject are presented in Appendix A.

Results were subjected to Pearson product-moment correlational analyses to determine the test-retest reliability of the treadmill protocol. Correlational coefficients of $r = .95$ were obtained for $\dot{V}O_2$ max and AT values.

Procedures

Subjects. Thirty-one female recreational runners residing in the Greensboro, North Carolina area during the spring semester of 1984 were recruited, through campus and newspaper advertisements, to participate voluntarily in the study. Physical characteristics of subjects appear in Table 1. Subjects were between 18 and 35 years of age with no evidence of cardio-respiratory disease. All subjects were running between 15 and 30 miles per week and were able to complete 5 and 10 km distances continuously at the time of the study. Subjects were apprised of the nature of the study and gave informed consent prior to participation. (See Appendix B).

Testing. All testing was conducted in the Rosenthal Human Performance Laboratory on the University of North Carolina at Greensboro campus and on premeasured 5 and 10 km courses. During the first testing session, subjects completed medical history and 24-hour recall surveys. (See Appendix B). Height, weight, and skinfold measures were determined

Table 1

Physical Characteristics of Subjects

Characteristic	n	$\bar{X}$	SD	Range
Age	31	26.7	4.82	18 - 35
Height (cm)	31	163.3	3.42	157.5 - 168.3
Weight (kg)	31	56.7	5.75	48.08 - 69.85
% Fat	30	21.1	4.03	14.14 - 30.79
FFW (kg)	30	44.59	3.49	40.13 - 54.03

for each subject. Selected skinfold measurement sites for the estimation of body density were the triceps, suprailiac, and thigh (Jackson, Pollock, & Ward, 1980). Lange calipers were used to take three readings at each skinfold site. Each reading was recorded to the nearest .5 millimeter. When two measurements differed by 4 mm or more, additional readings were made. The means of the closest three readings were summed to estimate body density. Percentage of body fat and fat-free weight were determined by subjecting the body density value to the formula derived from Brozek, Grande, Anderson, and Keys (1963).

Each subject underwent a continuous incremental maximal treadmill test for the determination of maximal oxygen uptake and AT. Subjects were instructed to refrain from caffeine, smoking, and large meals 3 hours preceding each test and from physical exercise on the day of the test. Standard open-circuit indirect calorimetry techniques were used to collect small samples of expired respiratory gases every minute throughout the administration of the protocol.

Protocol. Treadmill speed began at 3 mph (80.46 m/min) and increased 1 mph (26.82 m/min) every 2 minutes up to 5 mph (134.10 m/min). Thereafter, speed increased .5 mph (13.41 m/min) every 2 minutes until volitional exhaustion. A constant 0% grade was maintained so that the relationship of the onset of AT with speed alone could be examined as suggested by Katch et al. (1978). One subject reached the maximal treadmill velocity (10 mph, or 268.20 m/min) before exhaustion. Therefore, the grade was raised to 2.5% at minute 26 and to 5% at minute 28. Treadmill velocity remained at 10 mph (268.20 m/min).

$\dot{V}_E$, $\dot{V}O_2$, and $\dot{V}CO_2$ were measured using a semi-automated system. Expired ventilation was assessed by a Pneumoscan S-301 Spirometer. Gas temperature was measured in degrees Centigrade by means of a thermistor inserted near the flow transducer of the spirometer. Fractions of expired O_2 and CO_2 were measured by a Beckman OM-11 analyzer and LB2 analyzer, respectively. Before each testing session, analyzers were calibrated using standard gases previously verified by the micro-Scholander technique. The CM5 bipolar lead configuration described by Blackburn et al. (1964) was used to obtain ECG recordings on a Beckman R411 recorder. Heart rate was assessed during the last 10 seconds of each minute of exercise.

The peak $\dot{V}O_2$ value attained during exhausting exercise was recorded as $\dot{V}O_2$ max. Supporting criteria included (a) heart rate within the range of estimated maximal for age, (b) R greater than 1.1, and (c) increases in $\dot{V}O_2$ of less than 150 ml with an increasing intensity during the final two workloads (Taylor, Buskirk, & Henschel, 1955). All subjects successfully met the $\dot{V}O_2$ max criteria.

During the second testing session, each subject completed a submaximal run on the treadmill. Three subjects did not undergo submaximal testing due to scheduling problems. The submaximal data of a fourth subject were excluded from data analyses because of noncompliance with pretesting requirements.

The submaximal testing protocol was identical to that used in maximal testing. However, exercise was terminated when subjects reached 85% $\dot{V}O_2$ max. Running performance data were collected during the final two testing sessions. During session 3, subjects were timed on one of two certified 10 km races held in the Greensboro, North Carolina area during February and March of 1984. For the final testing session, subjects were timed on a premeasured 5 km course. Times on both runs were recorded in minutes and seconds.

Determination of the anaerobic threshold. Gas exchange variables for the determination of AT included $\dot{V}_E$ BTPS ($l \cdot min^{-1}$), $\dot{V}O_2$ ($l \cdot min^{-1}$), $\dot{V}O_2$ ($ml \cdot kg \cdot min^{-1}$), $\dot{V}CO_2$ ($l \cdot min^{-1}$), FE_{O_2} (%), FE_{CO_2} (%), and R as suggested by Davis et al. (1976). All ventilatory parameters were measured at 1-minute intervals and plotted against treadmill velocity in meters per minute every 2 minutes. The treadmill velocity associated with the onset of the AT was that which generated a systematic increase in the ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}O_2$) without a corresponding increase in the ventilatory equivalent for CO_2 ($\dot{V}_E/\dot{V}CO_2$) (Davis et al., 1979). Other criteria for AT determination included (a) the point of linearity departure of $\dot{V}_E$ and $\dot{V}CO_2$, (b) abrupt increases in FE_{O_2}, and (c) abrupt increases in R (Wasserman et al., 1973). Computer software programs were designed to plot the variables against treadmill velocity. Location of the AT was specified by visual inspection. Two investigators independently assessed the plotted data.

Anaerobic threshold values and associated treadmill velocities were calculated from maximal and submaximal testing. The mean of the two assessments was used to represent AT (McLellan & Skinner, 1981). Physiological assessments derived from maximal testing were used for those subjects who did not perform submaximal exercise.

Statistical Analyses. Means, standard deviations, and ranges of the physiological parameters generated from treadmill tests, body composition assessments, and running performances were computed and presented in tabular form. Pearson product-moment correlation coefficients were calculated to examine the interrelationships between 11 physical and physiological measures and two running performance times. An alpha level of .05 was used to test the significance of correlations.

The data generated from assessments of all physical and physiological variables and running performance times were subjected to two stepwise multiple regression analyses. Such a design made it possible to determine how much of the variation in the dependent variables (5 km and 10 km performance times) was accounted for by the effects of the independent measures. The dependent variables were defined as time, to the nearest second, to complete the 5 km and 10 km distances. The independent variables were age, height, weight, percentage of fat, fat-free weight, $\dot{V}O_2$ max (l.min), AT (ml•kg•min^{-1}), percentage of AT-$\dot{V}O_2$, treadmill velocity at AT, and $\dot{V}_E$-AT.

A variation of stepwise regression was applied to the physiological variables while partialing out the variability of the demographic data. The forced entry regression analysis followed by forward selection procedures was conducted to examine the predictive power of the physiological variables while adjusting for age, height, weight, percentage of fat, and fat-free weight.

CHAPTER IV

RESULTS

Thirty-one female recreational runners were subjected to maximal and submaximal treadmill exercise for the determination of the anaerobic threshold. In addition, subjects were timed on 5 km and 10 km distances for the assessment of the relationship between AT, treadmill velocity associated with AT, and distance running performance.

Maximal and Submaximal Treadmill Testing

Maximal and submaximal treadmill tests were administered to 31 and 28 subjects, respectively, for the evaluation of maximal oxygen uptake and anaerobic threshold. Means, standard deviations, and ranges of variables assessed during treadmill tests and running performance times are presented in Table 2. Individual results for all subjects on all parameters are shown in Appendix C.

Two independent investigators concurred on the location of the AT for all subjects on the maximal test data and on 25 of 27 subjects on the submaximal data. Discrepancies occurred on values of subjects who ran only a short time on the submaximal test. Scatterplots for such subjects contained an insufficient number of data points to clearly reveal the departure of $\dot{V}_E\dot{V}O_2$ from linearity.

A t test for dependent groups was applied to the mean AT values resulting from the maximal and submaximal treadmill tests. There was no significant difference ($p>.05$) between AT-$\dot{V}O_2$ values obtained during the two testing sessions. The test-retest correlation coefficient for the

Table 2

Physiological Characteristics and Performance

Times of Subjects

Variable	n	$\bar{X}$	SD	Range
$\dot{V}_E$ max $(l \cdot min^{-1})$BTPS	31	96.72	11.73	72.7 - 117.0
$\dot{V}O_2$ max $(l \cdot min^{-1})$	31	2.556	.31	2.06 - 3.22
$\dot{V}O_2$ max $(ml \cdot kg \cdot min^{-1})$	31	45.42	5.83	35.05 - 61.80
$\dot{V}_E$-AT $(l \cdot min^{-1})$BTPS	31	57.51	10.45	38.0 - 79.9
AT-$\dot{V}O_2$ $(l \cdot min^{-1})$	31	1.978	.25	1.596 - 2.67
AT-$\dot{V}O_2$ $(ml \cdot kg \cdot min^{-1})$	31	34.98	3.759	29.01 - 43.21
% AT-$\dot{V}O_2$	31	.79	.089	.62 - .90
TM Velocity at AT (m/min)	31	152.5	18.8	128.7 - 214.6
5 km run	31	26:08	3:48	18:43 - 36:30
10 km run	31	53:27	7:40	36:55 - 71:17

AT ($l \cdot min^{-1}$) was r=.93. A lower r of .61 was obtained when AT was examined relative to body weight. However, excluding the data of two subjects whose max-submaximal AT values were considerably different improved the r value to .72.

A Pearson product-moment correlational analysis was conducted to provide a better understanding of the interrelationships between 11 physical and metabolic parameters and 2 distance-running performances. Results of the correlational procedure appear in Table 3.

Significant correlations (r=-.58, r=-67, p<.001) were noted between relative $\dot{V}O_2$ max and 5 km and 10 km performance times, respectively.. In contrast, no significant relationship was observed between absolute $\dot{V}O_2$ max and running performance at either distance. Similarly, no significant relationships were noted between either absolute or relative AT-$\dot{V}O_2$ values and performance times. However, the percentage of AT-$\dot{V}O_2$ was significantly related to 10 km (r=.4511, p<.01) and 5 km (r=.39, p<.05) performance times.

The relationships between treadmill velocity corresponding to AT and running performance times were significant. Correlations of r=-.46 (p<.01) and r=-.42 (p<.05) were noted between treadmill velocity at AT and times for the 10 km and 5 km distances, respectively. Treadmill velocity and relative AT-$\dot{V}O_2$ values were significantly related as well (r=.45, p<.01).

Relatively strong associations were observed between AT and $\dot{V}O_2$ max values. Significant correlations of r=.62 and r=.58 (p<.01) were noted between absolute AT and $\dot{V}O_2$ max and relative AT and $\dot{V}O_2$ max, respectively.

Table 3

Correlations Among Physiological Variables and Performance Times

	AGE	WT	FAT	FFW	HVO2ML	HVO2L	TEHK	FIVEK	VEBTPS	ATL	ATHL	PERMAX	THVEL	VEAT
AGE	1.0000 (31) P= .	-.0467 (31) P= .803	.1305 (30) P= .492	-.1510 (30) P= .426	.0481 (31) P= .797	.0013 (31) P= .994	-.0439 (30) P= .818	-.0453 (30) P= .812	.2703 (31) P= .141	.0503 (31) P= .788	.1145 (31) P= .540	.0955 (31) P= .609	-.0949 (31) P= .611	.245 (31 P= .18
WT	-.0467 (31) P= .803	1.0000 (31) P= .	.6670 (30) P= .000	.8640 (30) P= .000	-.4338 (31) P= .015	.3441 (31) P= 058	.5945 (30) P= .001	.5779 (30) P= .001	.5040 (31) P= .004	.5239 (31) P= .002	-.2916 (31) P= .111	.2050 (31) P= .268	-.1327 (31) P= .477	.579 (31 P= .00
FAT	.1305 (30) P= .492	.6670 (30) P= .000	1.0000 (30) P= .	.2049 (30) P= .277	-.6153 (30) P= .000	-.1091 (30) P= .566	.6186 (29) P= .000	.6185 (29) P= .000	.1851 (30) P= .327	.0994 (30) P= .601	-.4816 (30) P= .007	.2504 (30) P= .182	-.1900 (30) P= .314	.315 (30 P= .09
FFW	-.1510 (30) P= .426	.8640 (30) P= .000	.2049 (30) P= .277	1.0000 (30) P= .	-.1562 (30) P= .410	.5387 (30) P= .002	.3647 (29) P= .052	.3425 (29) P= .069	.5196 (30) P= .003	.6419 (30) P= .000	-.0540 (30) P= .777	.1158 (30) P= .542	-.0450 (30) P= .813	.568 (30 P= .00
HVO2ML	.0481 (31) P= .797	-.4338 (31) P= .015	-.6153 (30) P= .000	-.1562 (30) P= .410	1.0000 (31) P= .	.6886 (31) P= .000	-.6710 (30) P= .000	-.5809 (30) P= .001	.1326 (31) P= .477	.1683 (31) P= .365	.5836 (31) P= .001	-.5578 (31) P= .001	.4150 (31) P= .020	-.227 (31 P= .21
HVO2L	.0013 (31) P= .994	.3441 (31) P= .058	-.1091 (30) P= .566	.5387 (30) P= .002	.6886 (31) P= .000	1.0000 (31) P= .	-.2172 (30) P= .249	-.1278 (30) P= .501	.5023 (31) P= .004	.6164 (31) P= .000	.3912 (31) P= .029	-.4033 (31) P= .024	.3212 (31) P= .078	.209 (31 P= .25
TEHK	-.0439 (30) P= .818	.5945 (30) P= .001	.6186 (29) P= .000	.3647 (29) P= .052	-.6710 (30) P= .000	-.2172 (30) P= .249	1.0000 (30) P= .	.9095 (29) P=0.0	.0767 (30) P= .687	.2117 (30) P= .261	-.2961 (30) P= .112	.4511 (30) P= .012	-.4639 (30) P= .010	.327 (30 P= .07
FIVEK	-.0453 (30) P= .812	.5779 (30) P= .001	.6185 (29) P= .000	.3425 (29) P= .069	-.5809 (30) P= .001	-.1278 (30) P= .501	.9095 (29) P=0.0	1.0000 (30) P= .	.0156 (30) P= .935	.2378 (30) P= .205	-.2659 (30) P= .155	.3926 (30) P= .032	-.4155 (30) P= .022	.328 (30 P= .07
VEBTPS	.2703 (31) P= .141	.5040 (31) P= .004	.1851 (30) P= .327	.5196 (30) P= .003	.1326 (31) P= .477	.5023 (31) P= .004	.0767 (30) P= .687	.0156 (30) P= .935	1.0000 (31) P= .	.4688 (31) P= .008	.1106 (31) P= .554	-.0288 (31) P= .878	.1261 (31) P= .499	.591 (31 P= .00
ATL	.0503 (31) P= .788	.5239 (31) P= .002	.0994 (30) P= .601	.6419 (30) P= .000	.1683 (31) P= .365	.6164 (31) P= .000	.2117 (30) P= .261	.2378 (30) P= .205	.4688 (31) P= .008	1.0000 (31) P= .	.6559 (31) P= .000	.4533 (31) P= .010	.2892 (31) P= .114	.667 (31 P= .00
ATHL	.1145 (31) P= .540	-.2916 (31) P= .111	-.4816 (30) P= .007	-.0540 (30) P= .777	.5836 (31) P= .001	.3912 (31) P= .029	-.2961 (30) P= .112	-.2659 (30) P= .155	.1106 (31) P= .554	.6559 (31) P= .000	1.0000 (31) P= .	.3275 (31) P= .072	.4529 (31) P= .010	.251 (31 P= .17
PERMAX	.0955 (31) P= .609	.2050 (31) P= .268	.2504 (30) P= .182	.1158 (30) P= .542	-.5578 (31) P= .001	-.4033 (31) P= .024	.4511 (30) P= .012	.3926 (30) P= .032	-.0288 (31) P= .878	.4533 (31) P= .010	.3275 (31) P= .072	1.0000 (31) P= .	-.0634 (31) P= .735	.583 (31 P= .00
THVEL	-.0949 (31) P= .611	-.1327 (31) P= .477	-.1900 (30) P= .314	-.0450 (30) P= .813	.4150 (31) P= .020	.3212 (31) P= .078	-.4639 (30) P= .010	-.4155 (30) P= .022	.1261 (31) P= .499	.2892 (31) P= .114	.4529 (31) P= .010	-.0634 (31) P= .735	1.0000 (31) P= .	.012 (31 P= .94
VEAT	.2451 (31) P= .184	.5791 (31) P= .001	.3152 (30) P= .090	.5683 (30) P= .001	-.2279 (31) P= .217	.2090 (31) P= .259	.3278 (30) P= .077	.3280 (30) P= .077	.5911 (31) P= .000	.6676 (31) P= .000	.7518 (31) P= .172	.5835 (31) P= .001	.0121 (31) P= .949	1.000 (31 P= .

Two stepwise regression analyses were applied to 11 physical and physiological variables for the prediction of two separate running performance times. Five and 10 km times served as dependent variables in the first and second analysis, respectively.

The results depicted in Table 4 indicate that relative and absolute $\dot{V}O_2$ max contributed significantly to the variability of 10 km performance time. Specifically, the analysis showed that the best predictor was relative $\dot{V}O_2$ max (B standardized = .98461, $F_{1,29} = 36.00$, $p<.01$). The second best predictor of 10 km performance time was absolute $\dot{V}O_2$ max (B standardized = .467611, $F_{1,29} = 7.219$, $p<.05$). The resulting raw score prediction formula was $y = 81.31583 - 1.22993X_1 + 10.88315X_2$ where $X_1 = \dot{V}O_2$ max ($ml \cdot kg \cdot min^{-1}$) and $X_2 = \dot{V}O_2$ max ($l \cdot min^{-1}$). Relative $\dot{V}O_2$ max alone accounted for a significant proportion of variability (44%) of 10 km performance. When absolute $\dot{V}O_2$ max was added, 55% of the variability in 10 km running performance was explained. When all remaining independent variables were added, 76% of the variability in 10 km running performance was accounted for.

In order to more clearly focus upon the effects of the physiological measures on running performance, the variability of the demographic data was parceled out. A forced entry regression analysis was applied to age, height, weight, percentage of fat, and fat-free weight. All variables but weight met the forced entry criteria. Age, height, percentage of fat, and fat-free weight combined to explain a significant proportion (46%) of the variability in 10 km performance.

Table 4

Comparative Effects of Relative and Absolute $\dot{V}O_2$ Max on 10 km Running Performance

Selected Variables	Beta Weight	Beta (Standardized)	Std Error	R^2	F
Max $\dot{V}O_2$ ($ml \cdot kg \cdot min^{-1}$)	-1.22993	-.98461	.21742	.4390	32.002*
Max $\dot{V}O_2$ ($l \cdot min^{-1}$)	1.88315	.46761	4.05102	.5540	7.220*

$$10\ km\ time = 81.3158 - 1.2293X_1 + 10.88315X_2$$

X_1 = max $\dot{V}O_2$ ($ml \cdot kg \cdot min^{-1}$)

X_2 = max $\dot{V}O_2$ ($l \cdot min^{-1}$)

*$p < .01$

In the subsequent forward selection procedure, treadmill velocity at AT emerged as the variable accounting for the most additional variability (16%) in 10 km performance. The only other variable selected into the equation was the percentage of AT-$\dot{V}O_2$, which explained an additional 6% of the variability. Thus, the four demographic variables along with treadmill velocity at AT and the percentage of AT-$\dot{V}O_2$ explained 68% of the variability in 10 km running performance.

Identical analyses were conducted to examine the effects of the independent variables on 5 km performance. Results of the stepwise regression analysis incorporating 5 km performance time as the dependent variable are shown in Table 5. Percentage of fat, treadmill velocity at AT, and absolute AT contributed significantly to the predictability of 5 km performance. The single best predictor was the percentage of body fat (B standardized = .49780, $F_{1,29}$ = 13.76, $p<.01$). The variable explaining the most additional variability was treadmill velocity at AT (B standardized = -.40960, $F_{1,29}$ = 8.63, $p<.05$). Percentage of body fat alone explained a significant proportion of the variability (36%). When treadmill velocity at AT was combined with percentage of body fat, 46% of the variability in 5 km performance was explained. Absolute AT, combined with percentage of body fat and treadmill velocity at AT, accounted for 54% of the variability in 5 km running performance. With the addition of the remaining independent variables, 66% of the variability in 5 km performance was explained.

As in the case of predicting 10 km performance time, the demographic variables were adjusted to clarify the effects of the physiological measures on 5 km performance. Again, fat-free weight, age, fat, and height entered the analysis while weight was excluded.

Table 5

Comparative Effects of Percentage of Fat

Treadmill Velocity at AT, and

Absolute AT on 5 km Running Performance

Selected Variables	Beta Weight	Beta (Standardized)	Std. Error	R^2	F
Percent fat	.42959	.49780	.11578	.3663	13.76**
Treadmill Velocity at AT	-.07447	-.40960	.02536	.4601	8.626**
Absolute AT	4.20990	.30614	1.89267	.5437	4.946*

$$5 \text{ km time} = 20.05937 + .42959X_1 - .07447X_2 + 4.2099X_3$$

X_1 = Percent fat

X_2 = Treadmill Velocity at AT

X_3 = Absolute AT

* p<.05 ** p<.01

The four selected demographic variables combined to account for 42% of the explained variability in 5 km performance. Again, treadmill velocity at AT was the variable that accounted for the most additional variability (11%). No other variables met the forward selection criterion. The combination of the four demographic characteristics and treadmill velocity accounted for 53% of the variability in 5 km performance.

A summary of R^2 values resulting from three regression analyses for both 10 km and 5 km performances is shown in Table 6. The analysis producing the greatest proportion of explained variability in both performances was the stepwise regression with all variables entered into the prediction equation. Such an analysis resulted in an accountability of 76% and 66% of the variability in 10 km and 5 km performances, respectively. The second best analysis for 10 km performance was the forced entry followed by forward selection procedure, which produced a combination of variables that accounted for 68% of the variability. In contrast, the stepwise regression including the three best predictors of performance was the second best analysis for 5 km performance. The stepwise procedure selected three variables that accounted for 54% of the variability in 5 km running time.

Table 6

Comparison of Proportions of Explained Variablity in Running Performance Resulting From Three Regression Analyses

	STEP	ENTER	Forced
10 km	r^2 = .554	r^2 = .759	r^2 = .684
5 km	r^2 = .544	r^2 = .658	r^2 = .529

Step = amount of variability explained by best predictors

Enter = amount of variability explained by best predictors and all other independent variables

Forced = amount of variability explained when demographic data were adjusted

CHAPTER V

DISCUSSION, SUMMARY, AND RECOMMENDATIONS

Discussion

Anaerobic threshold is the point of linearity departure of $\dot{V}_E/\dot{V}O_2$ without a corresponding increase in $\dot{V}_E/\dot{V}CO_2$ during progressive exercise. Numerous investigators reported a strong relationship between the AT and distance-running performance (Kumagai et al., 1982; Powers et al., 1983; Tanaka et al., 1981; Thorland et al., 1980).

In the present study, $\dot{V}O_2$ max and variables associated with the AT were measured in female recreational runners. The primary purpose was to determine and report AT responses of such runners subjected to maximal and submaximal treadmill exercise.

The mean AT-$\dot{V}O_2$ value of 34.98 $ml \cdot kg \cdot min^{-1}$ resulting from the present investigation was within the range of values reported in other AT studies (Dwyer & Bybee, 1983; LaFontaine et al., 1981; Rusko et al., 1980; Thorland et al., 1980; Weltman & Katch, 1978). In the present study, mean AT-$\dot{V}O_2$ occurred at a higher O_2 uptake and was 7% higher when expressed as a percentage of max $\dot{V}O_2$ compared to values reported for other female recreational runners (Dwyer & Bybee, 1983). However, in comparison to female cross-country runners (Thorland et al., 1980) and skiers (Rusko et al., 1980), mean AT-$\dot{V}O_2$ ($ml \cdot kg \cdot min^{-1}$) and percentage of AT-$\dot{V}O_2$ values were lower in the present investigation. Such results can be explained by differences in fitness levels of subjects across investigations.

An interesting observation is the slightly higher mean AT-$\dot{V}O_2$ value of runners in the present study compared to that of untrained male subjects (Weltman & Katch, 1978). Similar findings are noted in comparisons of $\dot{V}O_2$ max values between male and female subjects of varying fitness levels (Bransford & Howley, 1977; Davis et al., 1979). Moreover, mean percentage of AT-$\dot{V}O_2$ was 78% in the present investigation and was in close agreement with 79% observed in highly trained male distance runners (LaFontaine et al., 1981). Davies and Thompson (1979) also observed similarities in performance between male and female runners when physiological measures were expressed in relative terms.

The treadmill velocity associated with the AT has been reported in several investigations (Farrell et al., 1979; LaFontaine et al., 1981; Rhodes & McKenzie, 1984; Sjodin & Jacobs, 1981). There is a lack of reported information concerning the treadmill velocity at which AT occurs in female subjects. However, studies involving male runners may be used for comparison. The average treadmill velocity at AT in the present study was considerably lower than that reported for male distance runners (Farrell et al., 1979; LaFontaine et al., 1981; Rhodes & McKenzie, 1984). Such a finding is logical since absolute and relative AT values in male runners were reportedly higher than in female runners (Dwyer & Bybee, 1983; LaFontaine et al., 1981; Powers et al., 1983; Thorland el al., 1980) and would therefore occur at higher treadmill velocities. However, one subject in the present investigation reached AT at the treadmill velocity of 214.0 m/min, which falls within the range of velocities reported for male distance runners (Farrell et al., 1979). The attainment of such a high velocity is not unusual. Although the subject was a recreational runner, as defined in the present study, her aerobic capacity was that of an elite distance runner.

Maximal oxygen uptake values have been reported in a number of studies of female athletes (Bransford & Howley, 1977; Daniels et al. 1977; Dwyer & Bybee, 1983; Wells et al., 1981; Wilmore & Brown, 1974). The mean $\dot{V}O_2$ max value in the present study was higher than that reported by Dwyer and Bybee (1983) for recreational runners. The difference in $\dot{V}O_2$ max values could be attributed to higher fitness levels of the subjects in the present study. The use of a bicycle ergometer protocol in the Dwyer and Bybee study versus the use of a treadmill protocol in the present investigation is an alternate explanation. It is well established that the treadmill generates higher max $\dot{V}O_2$ values due to the involvement of a larger active muscle mass (Astrand & Rodahl, 1977). Mean aerobic capacity was similar to that observed in female physical education majors (Bransford & Howley, 1977) but considerably lower than that of highly trained runners (Conley et al., 1981; Daniels et al., 1977; Thorland et al., 1980; Wilmore et al., 1974). Such a result is not surprising since the highly trained runners were characterized by markedly lower percentages of body fat and were presumably exposed to more rigorous training programs.

Three null hypotheses were tested in the present investigation. The first was that no significant relationship exists between AT and running performance. The results did not support the hypothesis. Neither absolute nor relative AT-$\dot{V}O_2$ values were significantly related to running performance even when correlational analyses were run on adjusted demographic data. However, other AT-associated variables were significantly correlated with the 5 km and 10 km events. Significant negative relationships between treadmill velocity at AT and running performances were observed in the present study. Strong relationships between treadmill velocity at AT and running success have been reported by other investigators at distances of 9.7 km (Farrell et al., 1979), 10 km (Londeree et al., 1984) 10 miles (Londeree et al., 1984), and the marathon (Farrell et al., 1984; Rhodes & McKenzie, 1984; Sjodin & Jacobs, 1981). Farrell et al. (1979) noted that treadmill velocity at AT was more closely related to 9.7 km performance than was any other variable.

The percentage of AT-$\dot{V}O_2$ was another variable found to be significantly related to distance running performance in the present study. However, positive relationships were observed between percentage of AT-$\dot{V}O_2$ and 10 km and 5 km performance times. Such results were not expected and conflict with findings of Kumagai et al. (1982). Although the correlations between performance times and percentage of AT-$\dot{V}O_2$ were not significant in the latter investigation, the direction of the relationships was negative. The reason for the discrepancy in results is unclear. It is possible that some subjects in the present investigation were not used to racing and therefore did not run competitively in the 5 km and 10 km events.

The insignificant association between AT-$\dot{V}O_2$ and running performance observed in the present investigation is not consistent with results of other studies (Kumagai et al., 1982; Powers et al., 1983; Tanaka et al., 1981; Thorland et al., 1980). The differences in findings of the present study and those of other investigations is not completely understood. However, it is plausible that the weak association between AT-$\dot{V}O_2$ and running performance can be attributed to the relatively homogeneous grouping of subjects on AT-$\dot{V}O_2$ values. Therefore, it would be misleading to conclude that AT-$\dot{V}O_2$ is an unimportant factor in distance-running success based on data resulting from the present study.

It is interesting to note that percentage of body fat was a variable that emerged in close association with running performance. Percentage of fat was the independent measure most highly related to the 5 km event and was second only to relative $\dot{V}O_2$ max in its relationship with the 10 km distance. The significant negative correlations between percentage of body fat and running performances were expected findings. Cureton and Sparling (1980) concluded that body fatness is detrimental to performance in activities that require movement of body weight.

The second null hypothesis stated that there is no significant relationship between AT and $\dot{V}O_2$ max. The results did not support the hypothesis. Significant correlations were observed betweeen absolute as well as relative AT and $\dot{V}O_2$ max. R values fell within the range of those reported for male subjects (Davis et al., 1976; Davis et al., 1979; Weltman & Katch, 1979) but were lower than those reported for untrained female subjects (Weltman et al., 1978) and recreational runners (Dwyer & Bybee, 1983).

The secondary purpose of the present investigation was to develop prediction equations for 5 and 10 km performance times based on $\dot{V}O_2$ max and variables associated with the anaerobic threshold. Data generated from all demographic and physiological measures and two running times were subjected to stepwise multiple regression analyses. Five km and 10 km performance times served as the dependent variables of the respective analyses. The two variables that best predicted 10 km performance time were relative and absolute $\dot{V}O_2$ max. Such findings are in agreement with those of other investigations (Costill, 1972; Saltin & Astrand, 1967). Davies and Thompson (1979) observed that $\dot{V}O_2$ max, combined with percentage of $\dot{V}O_2$ max, formed the best predictive model for marathon and ultramarathon performance in male runners. However, when the effects of the demographic data were parceled out in the present study, treadmill velocity at AT and percentage of AT-$\dot{V}O_2$ emerged as the best predictors of 10 km performance. It is likely that the $\dot{V}O_2$ max measures lost predictive power in the secondary analysis due to their high correlations with weight, percentage of fat, and fat-free weight. (See Table 3). Therefore, when subjects are equated on physical measures, AT variables unrelated to physical characteristics play an important role in the prediction of 10 km performance. The treadmill velocity at AT was found to be an important predictor of running performance in other studies as well (Farrell et al., 1979; Londeree et al., 1984). Londeree et al. (1984) noted that $\dot{V}O_2$ max and treadmill velocity at AT was the best combination of predictors of 10 km performance in female runners. Treadmill velocity at AT alone was the best predictor for the slightly shorter 9.7 km distance among male runners (Farrell et al., 1979).

A second stepwise regression analysis was applied to all physical and physiological variables to determine the best prediction equation for 5 km performance. The three variables entered into the equation were percentage of body fat, treadmill velocity at AT, and absolute AT. When the effects of the demographic data were parceled out, only treadmill velocity AT was entered into the equation. AT-associated variables were reportedly the best predictors of 5 km running performance in other studies as well. AT-$\dot{V}O_2$ was the best predictor for the 5 km distance for young male distance runners (Kumagai et al., 1982) and female collegiate cross-country runners (Thorland et al., 1980). In contrast, Londeree et al. (1984) found that $\dot{V}O_2$ max and the treadmill velocity corresponding to the second "breakaway" in ventilation formed the best predictive model for 5 km performance.

A comparison of proportions of explained variability in 5 and 10 km performances resulting from the three regression procedures in the present investigation appears in Table 6. The stepwise analysis including all independent variables explained the largest amount of variability in both 5 and 10 km events. A combination of all variables accounted for 76 and 66% of the variablility in 10 and 5 km running times, respectively. Such results indicate that factors other than those considered in the present study contribute to distance-running performance. Other physiological variables that could possibly provide additional information are running economy (Conley & Krahenbuhl, 1980; Costill & Winrow, 1970), fractional utilization of $\dot{V}O_2$ max (Costill et al., 1973; Davies & Thompson, 1979), and anaerobic threshold mechanisms associated with the second "breakaway" in ventilation (Londeree et al., 1984).

The final null hypothesis stated that there is no significant relationship between AT-$\dot{V}O_2$ and treadmill velocity. The results did not support the hypothesis. A positive significant relationship between relative AT-$\dot{V}O_2$ and treadmill velocity was observed. The significant association between the two variables has important ramifications in exercise prescription. Prior studies in which a similar relationship between AT-$\dot{V}O_2$ and treadmill velocity was established (Farrell et al., 1979; Sjodin & Jacobs, 1981) incorporated protocols with progressive increases in grade as well as velocity throughout testing. The third purpose of the present investigation was to utilize a protocol in which treadmill elevation was maintained at 0% throughout testing so that the relationship between AT-$\dot{V}O_2$ and treadmill velocity alone could be examined, as suggested by Katch et al. (1978).

In order to test the adequacy and reliability of the protocol used in the present study, a pilot study was designed and conducted. The protocol, in which velocity increased every 2 minutes while grade was maintained at 0%, generated reliable maximal $\dot{V}O_2$ and AT values in the pilot study and in the present investigation. It is suggested that future investigations incorporate two maximal treadmill tests rather than terminating the second at 85% $\dot{V}O_2$ max. A practical application extending from the treadmill velocity AT-$\dot{V}O_2$ association is the use of such a velocity as a training criterion. At the onset of the present investigation, training intensities relative to the AT had been prescribed only for the bicycle ergometer (McLellan & Skinner, 1981; Sady et al., 1980).

Summary

$\dot{V}O_2$ max and AT-$\dot{V}O_2$ related values were determined and reported for 31 female recreational runners. The subjects in the present study were characterized as having higher aerobic capacities and AT values compared to the recreational runners in the Dwyer and Bybee investigation (1983). Values were lower than those of trained distance runners, however (Conley et al., 1981; Daniels et al., 1977; Thorland et al., 1980; Wilmore & Brown, 1974).

Predictive models were established for running performances at distances of 5 km and 10 km for female recreational runners. Absolute and relative $\dot{V}O_2$ max were the best predictors of 10 km performance. However, when subjects were equated on demographic characteristics, treadmill velocity at AT and percentage of AT-$\dot{V}O_2$ emerged as the most important variables in the prediction equation.

Percent body fat, treadmill velocity at AT, and absolute AT were the best predictors of 5 km performance. When physical characteristics were adjusted, treadmill velocity at AT alone was entered into the regression equation.

A protocol in which a 0% grade was maintained while velocity progressively increased throughout testing was shown to generate reliable $\dot{V}O_2$ max and AT values. It was suggested that such a protocol can be used to prescribe exercise intensity relative to the AT.

Recommendations

Continued research into the area of AT could lead to more accurate prediction equations for distance-running performance. Inclusion of variables such as running economy, fractional utilization of $\dot{V}O_2$ max, and the second "breakaway" in ventilation might provide more insight into mechanisms related to successful performance among recreational runners. In addition, alternate statistical analyses should be applied to performance-related variables to clarify the relationship between such variables and running performance. Factor analysis would be a logical alternative to regression analysis to determine underlying patterns for a large number of physiological variables. The utilization of factor analysis could possibly condense information provided by the independent variables into a smaller set of components.

More research is needed in the area of exercise prescription based on AT values. Results from training studies in which exercise intensity is prescribed relative to $\dot{V}O_2$ max have shown wide ranges of improvement among individuals with similar levels of fitness (McLellan & Skinner, 1981). However, if subjects train at the same percentage relative to their anaerobic thresholds, a more individualized training criterion may be implemented.

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APPENDIX A

INDIVIDUAL DATA OF PILOT STUDY

Selected Individual Physical and

Physiological Measurements of Pilot Study

Subject	Age	HT (cm)	WT (kg)	Trial 1 $\dot{V}O_2$ max ($ml \cdot kg \cdot min^{-1}$)	Trial 1 AT ($ml \cdot kg \cdot min^{-1}$)	Trial 2 $\dot{V}O_2$ max ($ml \cdot kg \cdot min^{-1}$)	Trial 2 AT ($ml \cdot kg \cdot min^{-1}$)
CF	28	162.6	59.9	48.48	39.08	49.53	40.71
MM	29	162.6	67.1	46.57	30.88	44.58	29.82
JI	32	165.7	61.2	36.01	26.18	37.71	28.27
DS	28	171.5	78.0	45.70	35.75	44.76	34.81
X	= 29.3	165.6	66.6	44.19	32.97	44.15	33.40
SD	= 1.89	4.22	8.25	5.58	5.64	4.86	5.614

APPENDIX B

MEDICAL HISTORY FORMS AND CONSENT FORM

Self-Administered Pre-Exercise Medical History Form

Page 1

NAME____________________________________ DATE_______________

Check X if Yes

PAST HISTORY: (Have you ever had?)		FAMILY HISTORY: (Have any of your relatives had?)		PRESENT SYMPTOMS REVIEW: (Have you recently had?)	
Rheumatic fever	( )	Heart attacks	( )	Chest pain	( )
Heart murmur	( )	High blood pressure	( )	Shortness of breath	( )
High blood pressure	( )	Too much cholesterol	( )	Heart Palpitations	( )
Any heart trouble	( )	Diabetes	( )	Cough on exertion	( )
Disease of Arteries	( )	Congenital heart disease	( )	Coughing of blood	( )
Varicose veins	( )	Heart operations	( )	Back pain	( )
Lung disease	( )	Other	( )	Swollen, stiff or painful joints	( )
Operations	( )	Do you awaken at night to urinate?	( )		
Injuries to back, etc.	( )				
Epilepsy	( )				

Explain____

____

Date of last complete physical examination_____________________________

Did results of the examination indicate any medical problem that might make it dangerous for you to participate in vigorous exercise?______________.

If yes, explain.____

____

Self-Administered Pre-Exercise Medical History Form

Risk Factors:

		Yes	No		
1. Smoking -	Do you smoke?	( )	( )		
	Cigarettes	( )	( )	How many?______	How many years?______
	Cigars	( )	( )	How many?______	How many years?______
	Pipe	( )	( )	How many times a day?______	How many years?______

How old were you when you started?______

In case you have stopped, when did you?______Why____________

2. Diet

What is your weight now?____1 year ago____ at age 21____

Are you dieting?____Why?____________________________________

3. Exercise

Do you presently engage in a systematic physical conditioning program?____

If yes, indicate type and amount of conditioning ________________________

____

Do you engage in sports______

What______________________How often__________________________________

How far do you think you walk each day?______________________________

Is your occupation - Sedentary ( )
Inactive ( )
Active ( )
Heavy work ( )

Do you have discomfort, shortness of breath or pain with moderate exercise?

________________. Specify ____

____

Were you a schoolboy or college athlete?______________

Specify____

Modified from the Physician's Handbook for Evaluation of Cardiovascular and Physical Fitness, 2nd Ed., prepared by the Tennessee Heart Association Physical Exercise Committee. Nashville: Tennessee Hea rt Association, 1972.

Signature______________________________Witness____________________________

24-Hour History

NAME______________________________HEIGHT________________

AGE______________________________WEIGHT________________

DATE______________________________

TIME______________________________

1. How much sleep did you get last night? (Please circle one)
   .5-1 1-1.5 2-2.5 3-3.5 4-4.5 5-5.5 6-6.5 7-7.5 8-8.5 9-9.5 10 (hours)

2. How much sleep do you normally get? (Please circle one)
   .5-1 1-1.5 2-2.5 3-3.5 4-4.5 5-5.5 6-6.5 7-7.5 8-8.5 9-9.5 10 (hours)
3. How long has it been since your last meal? or snack? (please circle one)
   .5-1 1-1.5 2-2.5 3-3.5 4-4.5 5-5.5 6-6.5 7-7.5 8-8.5 9-9.5 10 (hours)

   List the items below:

4. When did you last have:
   A cup of coffee or tea
   Cigarettes
   Drugs (which include aspirin)
   Alcohol

5. What sort of physical exercise did you perform yesterday?

6. What sort of physical exercise have you performed today?

7. Describe your general feelings by checking one of the following:
   ____Excellent
   ____Very, very good
   ____Very good
   ____Good
   ____Neither good nor bad
   ____Bad
   ____Very bad
   ____Very, very bad
   ____Terrible

Informed Consent

I, _______________ volunteer to participate in the study entitled "Relationship of the Anaerobic Threshold and Running Performance in Female Recreational Runners" to be conducted at UNC-Greensboro during the spring semester of 1984.

I understand that the study will involve 4 sessions. Procedures are as follows:

During session 1, body composition will be estimated by skinfold measures. A maximal treadmill test will also be administered. Testing will involve using a headgear, nose clip, breathing valve, and EGG electrodes. Subjects will continue as long as possible and voluntarily terminate the test when fatigued.

Session 2 will involve a submaximal treadmill run. The testing will be identical to the maximal test but will terminate when subjects reach a heart rate corresponding to 85% of max .VO. Should values of physiological variables differ considerably from those obtained during the first test, a second submaximal test will be given.

Sessions 3 and 4 will involve 3.1 and 6.2 mile runs respectively. The 3.1 mile course will be in the vicinity of UNC-G. In order to establish running times for the 6.2 mile distance, subjects will be asked to enter the Valentine 10K run to be held in Greensboro in February 1984.

I understand that I am free to withdraw from participation at any time. I am also guaranteed anonymity after the data have been collects.

_________________________   _____________________

Subject   Date

APPENDIX C

RAW DATA

Raw Data

ID	AGE	HT	WT	FAT	FFW	MVO2ML	MVO2L	TEN-K	FIVE-K	VEBTPS	ATL	ATML	PERMAX	TMVEL	VEAT
01	21	165.1	58.06	24.37	43.91	41.16	2.390	51.15	27.44	92.8	1.844	31.76	.772	154.22	50.6
02	25	162.6	58.06	24.38	43.90	42.77	2.483	54.57	31.59	96.5	2.018	34.72	.811	174.33	65.7
03	27	162.6	54.88	18.98	44.46	38.86	2.133	59.58	28.51	72.7	1.614	29.50	.759	134.10	48.1
04	25	167.6	54.20	20.21	43.25	53.04	2.875	51.40	25.04	110.1	1.776	32.76	.618	140.81	56.2
05	29	158.8	51.71	15.31	43.79	54.45	2.816	47.41	25.22	100.3	1.682	32.41	.595	134.10	44.8
06	35	158.8	55.45	26.07	40.99	43.92	2.435	59.58	30.15	87.7	1.723	31.41	.715	134.10	47.2
07	28	161.3	53.40	20.21	42.61	43.95	2.345	47.27	23.57	86.1	1.596	29.89	.680	160.92	38.0
08	21	159.4	57.95	18.98	46.95	45.30	2.625	55.29	25.49	88.0	2.079	35.69	.788	147.51	52.5
09	34	160.0	56.36	20.21	44.97	51.95	2.928	43.05	22.43	102.9	2.047	36.32	.699	134.10	54.2
10	18	167.6	54.88	17.34	45.36	47.96	2.632	52.11	24.43	90.4	2.005	36.38	.759	154.22	58.4
11	26	160.7	52.84	18.16	43.24	40.47	2.138		26.20	78.5	1.881	35.29	.872	140.81	64.0
12	18	158.8	53.54	18.98	43.38	49.75	2.663	43.28	22.28	80.5	1.685	31.58	.635	154.22	43.5
13	27	168.3	68.97	27.35	50.11	37.31	2.573	65.45	32.10	103.3	2.122	31.05	.832	128.74	68.6
14	23	168.3	64.64	23.54	49.42	46.47	3.004	71.17	36.30	101.0	2.582	40.01	.861	147.51	63.9
15	29	162.6	55.57			49.76	2.753	47.02	24.22	90.6	2.160	38.96	.868	140.81	70.6
16	35	162.6	62.27	30.79	43.10	36.35	2.263	62.00	29.05	108.9	2.049	32.66	.898	154.22	79.9
17	29	163.8	48.08	14.14	41.28	61.80	2.971	36.55	18.43	108.7	2.022	42.05	.680	214.56	56.5
18	24	165.1	56.02	18.16	45.85	43.57	2.411	56.50	25.38	109.5	1.849	33.20	.762	147.51	62.4
19	32	160.0	50.80	18.16	41.57	49.99	2.539	47.27	23.47	93.2	1.948	38.35	.767	147.51	48.7
20	23	168.3	56.36	24.38	42.62	43.56	2.455	52.42	25.02	88.4	1.966	34.96	.803	167.63	50.0
21	31	167.6	59.42	21.87	46.42	41.18	2.405	59.46	26.57	110.1	2.086	35.41	.860	147.51	64.1
22	21	161.3	50.92	19.80	40.84	40.37	2.056	47.04	24.17	82.6	1.719	33.63	.833	174.33	44.2
23	31	168.3	64.41	16.12	54.03	49.97	3.219	46.15	23.17	117.0	2.677	41.55	.831	187.74	79.0
24	24	165.7	69.85	26.07	51.64	35.05	2.448	60.28	29.39	113.1	2.026	29.01	.828	134.10	73.1
25	22	161.3	57.27	19.80	45.93	51.99	2.977	55.40	26.42	89.6	2.356	41.15	.791	174.33	52.2
26	23	167.6	60.63	24.80	45.59	41.13	2.494	63.00		99.1	1.847	30.45	.740	147.51	50.0
27	34	163.2	52.62	23.12	40.45	44.74	2.354	51.03	23.36	92.4	1.890	35.85	.801	167.63	52.4
28	32	163.8	48.08	16.53	40.13	43.20	2.077	57.01	27.48	86.5	1.893	38.65	.895	134.10	61.7
29	25	160.0	51.03	20.62	40.51	47.89	2.444	51.22	25.12	93.5	2.120	40.15	.838	154.22	60.2
30	26	157.5	50.80	17.01	42.06	43.67	2.218	50.42	24.07	107.4	1.891	37.02	.848	134.10	55.4
31	29	162.6	67.13	26.49	49.35	46.57	3.126	54.01	26.31	116.8	2.178	32.45	.697	160.92	66.8