CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

A COMPARISON OF A CONTINUOUS PROTOCOL
AND A PROTOCOL WITH A PERFORMANCE BREAK
FOR THE MEASUREMENT OF VO₂ MAXIMUM

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Arts in

Physical Education

by

Robert Lisle Hutton

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The Thesis of Robert Lisle Hutton is approved:

Dr. George Q. Ritch

Dr. Judith Brame

Dr. George J. Holland,
Committee Chairman

California State University, Northridge

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ABSTRACT

A COMPARISON OF A CONTINUOUS PROTOCOL
AND A PROTOCOL WITH A PERFORMANCE BREAK
FOR THE MEASUREMENT OF VO₂ MAXIMUM

by

Robert Lisle Hutton

Master of Arts in Physical Education

The purpose of this study was to compare the
VO₂ maximum measurements obtained by using an interrupted
treadmill protocol (Maksud Protocol) with those values
obtained by using a protocol that included a two-minute
performance break. A secondary purpose was to assess
subject preference for one or the other protocol.

Eleven healthy endurance trained male athletes
whose mean age was 24.1 years, volunteered as subjects.
Subjects were randomly assigned to Group I or Group II.
Group I performed the Maksud Protocol first and the
Alternate Protocol one week later. Group II performed the
Alternate Protocol first and the Maksud Protocol the next week.

The major findings were as follows:

1. There was no significant difference between the VO₂ max measures obtained by using the Maksud Protocol and those obtained using the Alternate Protocol.

2. There was no significant difference in the subjects' expressed preference for the Maksud Protocol and of the Alternate Protocol.
CHAPTER I

INTRODUCTION

The measurement of oxygen uptake (VO$_2$) has often been called the "Gold Standard" of cardio-vascular fitness testing. Researchers use the results of oxygen uptake tests to determine the efficacy of various training regimes, to test innovative training and therapy procedures against more traditional forms, and to evaluate the "fitness" of individuals and populations.

Since maximal oxygen uptake tests of the general populace or of cardiac patients can entail hazardous situations, walking and bicycle tests and some field testing procedures, all at sub-maximum levels, have been developed. These sub-maximum tests, used as predictors of maximal levels, are useful tools in this context and have proven to be quite adequate (Auchinclass & Gilbert, 1973; Glassford, 1965; Maksud & Coutts, 1971; Ribisl & Kachadorian, 1969).

For highly conditioned individuals, it becomes necessary to seek a higher level of accuracy and more refined methods of distinction to measure VO$_2$ max since
the population tends to be homogenous and the differences small but significant. Although it is well established that an athlete's ability to take in oxygen is not a direct predictor of his competitive performance, it is the most highly correlated physiological measure available. deVries (1980) reports negative correlations of .84, .87 and .88 between VO$_2$ max and the one, two and six-mile runs respectively. The negative correlation for performance at a steady speed was even more significant, .94. Interest in tangible parameters such as this one is high among coaches, athletes and other parties interested in eliciting maximum performance in competitive situations (Costill, 1968, 1979; deVries, 1980; Pollack, 1978).

Athletes want as much scientific information as possible regarding physiological parameters, and take pleasure in comparing their own laboratory results with those of the elite competitor. They will frequently seek comparative data through retesting at a later date, often after a specific time and/or training regime (Costill, 1979; Pollack, 1978).

Coaches seek knowledge that will help them guide their athletes in the quest for improvement in whatever manner they can. If the laboratory provides them with results in a prompt and clear manner, there can be a mutually beneficial relationship developed between the laboratory and the field. By obtaining and understanding
the implications of laboratory results, the coach will be better able to evaluate the various sources regarding the effectiveness of a particular training program.

When working with competitive athletes, it becomes necessary to acquire accurate, consistent and dependable results, while creating a pleasant, informative atmosphere in the laboratory and giving every consideration to the welfare of the subject.

The laboratory technician in exercise physiology is interested in efficient, accurate and reliable methods that yield the finest physiological distinctions possible. He/she must also address the problem of laboratory expense which translates to efficient use of time, equipment and personnel.

This study seeks to refine the protocol for the laboratory measurement of maximal oxygen uptake to give the subject every chance to reach maximal levels with minimal discomfort while preserving the economical use of laboratory time, equipment and personnel.

**The Problem**

**Statement of the Problem**

The problem under consideration was to determine if a protocol incorporating a "performance break" (Alternate Protocol) prior to the maximal effort during the testing for VO$_2$ max would produce results similar to a
traditional discontinuous protocol (Maksud Protocol).

**Statement of the Purpose**

The purpose of this study was to determine the
effect of incorporating a standardized rest period into
the laboratory test for VO_2max on the resulting measure-
ment of maximum oxygen consumption.

**Hypothesis**

The investigation was designed to test the
following hypothesis: no significant difference exists
between subjects' performance on a continuous protocol
versus an interrupted laboratory protocol, as measured by
maximum oxygen uptake.

**Importance of Study**

This study concerns a topic of significant
interest to researchers who use maximal oxygen uptake
measurement as a basic tool of laboratory investigation.
If subjects are able to achieve a higher level of oxygen
consumption or to achieve maximal physiological perform-
ance with less discomfort by using the alternate protocol,
results should be more consistent since subjects are
approaching their true limits more regularly. Also, by
using the alternate protocol, it may be easier to recruit
subjects and gain subject confidence and cooperation.
Thus, subjects may be more willing to return for repeat work and for other laboratory tests if the level of discomfort is kept minimal.

Maksud and Coutts (1971) found that heart rate and breathing frequency were higher during a continuous protocol than during a discontinuous protocol. Researchers have also recorded higher temperatures in a continuous protocol than in a discontinuous protocol (Froelicher, Brammell, Davis, Noguera, Stewart & Lancaster, 1974). They suggested that the reason for higher VO\textsubscript{2} recordings on the discontinuous protocol might be related to A-V shunting caused by the higher temperature in the continuous protocols.

The two-minute performance break in the present study allowed the subject's breathing and heart rates to recover and his body temperature to decrease. These physiological changes could contribute to an increase in VO\textsubscript{2} max recordings. That the two minutes rest is adequate time for physiological recovery mechanisms to function is evidenced by the fact that Astrand (1970) found that micro pauses of five and ten seconds allowed subjects to perform work loads several times greater than they were able to tolerate without the breaks. He hypothesized that oxygen may be stored in the muscles as oxymyohemoglobin during the breaks and utilized when work resumed to delay anaerobic metabolism. He also found that blood lactates
were lower and subjective discomfort reduced when breaks were introduced.

With the physiological advantages of a test break and the savings in laboratory time, the alternate protocol is of interest as an alternative method for testing VO₂max.

Scope and Limitations

This study employed male members of the track and fencing teams from California State University, Northridge; and competitive non-collegiate distance-runners. Subjects were required to perform two maximal work capacity tests within one week. The subjects had been running an average of thirty to ninety miles per week for from six months to several years prior to the study. All subjects agreed to a training maintenance requirement which was designed to limit possible training or detraining effects from performance on the treadmill running. Previous practice on the treadmill was performed by all subjects to diminish practice effects during the tests. Both tests were performed at the same time of day and by the same laboratory team.

The study was limited by the difficulty of verifying the training of the subjects. Factors such as intelligence and motivation were not considered in relation to this experiment. Although an attempt was made to
limit the study to endurance trained athletes, no attempt was made to obtain a random or representative group of runners.

Results of this study are not generalizable to untrained subjects, other age groups, or to females.

Definition of Terms

Alternate Protocol

A protocol that is continuous except for a single two-minute performance break near the end of the test.

Continuous Protocol

A protocol that requires the subject to perform work until maximum work capacity or a desired submaximal level is reached without any performance breaks.

Discontinuous Protocol

A protocol that incorporates multiple performance breaks while bringing the subject to maximum or pre-designated sub-maximum levels.

Endurance Trained Subjects

A subject who has been steadily running at least thirty miles a week for six months or more.

Maksud Protocol

A continuous protocol used by Maksud, et al. (35). This was the continuous protocol used in this study.
Maximum Work Capacity

The maximum level of work a subject can perform as measured by oxygen uptake.

$VO_2max$: Maximum Oxygen Uptake

The greatest amount of oxygen the subject is able to absorb during maximum physical exertion.

Oxygen Uptake

The amount of oxygen absorbed by a subject during work on the treadmill.

ML/KG/MIN

Milliliters of oxygen per kilogram of body weight per minute of work on the treadmill; the comparative measure of oxygen absorption used in this study.

Performance Break

A cessation of work during a protocol during which the subject partially or fully recovers from the previously performed work.

Submaximal Test

A test that does not require a subject to perform to the maximum level of his capability, but yields results that permit an estimation of maximum performance levels.

Organization and Content of Remaining Chapters

This thesis is organized into six chapters. The following topics will be covered in the remaining chapters.
Chapter II contains a review of related literature. Chapter III describes the research design and procedural details followed in this study and a description of the statistical procedure utilized.

Chapter IV gives a presentation and interpretation of the statistical data. Chapter V is a discussion of the study and Chapter VI is a summary. Chapter VI also presents findings, conclusions and recommendations for further investigation.
CHAPTER II

REVIEW OF THE LITERATURE

Exercise physiologists have associated endurance performance with the body's ability to consume oxygen since the early 1920's when Hill and Lupton (1923) began experimentation in this area (Astrand, 1970, 1971; Bergh, Kanstrup & Ekblom, 1976; Bergh, Thortensson, Bertil, Bodil, Piehl & Karlsson, 1978; Bock, 1963; Costill, 1967; Koeslag & Sloan, 1976; Pollack, 1978; Saltin & Astrand, 1967; Slonim, 1957; Stamford, 1975; Taylor, Buskirk & Henshel, 1955). It appears that the relationship between endurance performance and oxygen uptake has now been well established (devVries, 1980).

Although VO$_2$ capability is recognized as a good indicator of performance potential and a reliable predictor of performance (devVries, 1980), it is not directly related to performance and is not a good predictor of competitive success (Costill, 1967; Pollack, 1978; Katch & Henry, 1972). Reasons for the lack of a relationship between oxygen consumption and performances are not clearly established. It may be due to an ability, thusfar
unexplained, of some competitors to maintain a higher percent of their maximum level for longer periods of time (Costill, 1970, 1976), to biomechanical factors in running efficiency (Pollack, 1978) and/or to measurement problems and lack of consistency in the assessment of VO$_2$max (Ricci, 1967).

The methods of measuring oxygen uptake varied considerably among early investigators. Taylor, Buskirk and Henshel (1955) were among the first to take a close look at the protocol as a possible source of error. They took steps to try to eliminate skill and motivation as factors and determined that raising the treadmill grade so the subject had to run "uphill" was more effective than increasing speed of the treadmill for eliciting VO$_2$. They established six to eight miles per hour as the ideal testing speed. They also found that the laboratory environment affected the performance of subjects. These included such factors as temperature and changing of the lab technicians, verbal encouragement and time of day.

Since bike ergometers are more readily available, much of the early work in VO$_2$max testing was done on bikes (Glassford, 1965; Mitchell, 1958; Ribisl, 1969; Wyndham, 1959). Later, interest was generated regarding the comparison of bike and treadmill tests results. It has since been clearly established that the treadmill test of VO$_2$max yields results about ten percent higher than
those obtained by the bike ergometer methods (Glassford, 1965; Hermansen & Saltin, 1979; McArdle, Katch & Pecar, 1973). The difference is somewhat less when the subject is allowed to pump at higher RPM's and lower resistance during the final minute of the test. When they are given this test, the difference is reduced to about 6% (Hermansen & Saltin, 1969). Walking tests have been shown to yield lower VO\textsubscript{2}max measures (McArdle, Katch & Pecar, 1973; Stamford, 1975) even when competitive race walkers are used as subjects (Stamford, 1975).

Many other methods have been devised to test VO\textsubscript{2}max, including step tests (Astrand, 1956), tests specified to swimmers (Bell & Ribisl, 1980), and tests with both arm and leg work (Bergh, Kanstrup & Ekblom, 1976; Carey, 1963; Gleser, 1974; Hagerman & Howie, 1971, 1979; Kamon, 1970, 1972). Most tests result in oxygen uptake measures lower than those obtained from treadmill running tests, with the exception of certain arm and leg combination tests which show equivalent or slightly higher results (Secher, 1974).

Astrand (1961) found that it was possible for subjects to reach maximal uptake levels in two minutes or less with results equal to protocols of eight minutes and longer.

Presently, exercise physiologist researchers use a variety of protocols ranging from very short,
highly intense, continuous protocols such as those used by Saltin and Astrand (1967) and Berg (1978), to rather long, discontinuous tests such as the Mitchell, Sproul, Chapman (1958) protocol.

**Comparing Discontinuous and Continuous Protocols**

Astrand (1961) performed experiments with short and long protocols and compared continuous and discontinuous protocols within same subjects. No significant differences were reported.

Maksud and Coutts (1971) compared a single session continuous graded treadmill test with a multi-session discontinuous procedure on young adults. They found no significant differences between the VO₂ max calculations obtained by the two methods, but did record significantly higher heart rates during the continuous procedure. This was attributed to the longer running time and the slightly higher workload required by the continuous method. They also noted that, though ventilation was not significantly different in the two tests, breathing frequency was higher in the continuous test, suggesting breathing pattern accommodations during prolonged, continuous work, at steady state. They found the discontinuous test to be more accurate, but concluded that the repeated laboratory visits and greater use of laboratory
time required by the discontinuous test were not justified by the small differences observed between the tests.

McArdle, Katch and Pechar (1973) compared six different methods of testing VO₂ max, two bicycle and four treadmill protocols. The bicycle tests averaged 10.2 to 11.6 percent below the treadmill running tests in the VO₂ max measures and six percent below the Balke walking test. The mean values for the Balke walking test were significantly lower than the running tests. Little difference was found between the two discontinuous running tests and the continuous one. The discontinuous tests were slightly higher, with a mean of 56.5 ml/kg/min as compared to 55.6 ml/kg/min for the continuous procedure. Since the discontinuous protocols involved breaks of ten minutes and since the difference between the tests was not significant, it was stated that the consideration of economical use of laboratory time and facilities would lead to the recommendation that the continuous test be used. It was felt that the subjects were able to "tolerate" the continuous test without undue stress.

Froelicher, Brammell, Davis, Noguera, Stewart and Lancaster (1974) compared the Bruce and Balke continuous protocols with the Taylor Discontinuous Protocol. The Taylor protocol produced a higher mean VO₂ max than the two continuous protocols. It was also stated that the Taylor program was the only one that produced consistent
plateauing at the maximum level. It was hypothesized that the cause of the lower mean oxygen consumption with the Bruce and Balke methods was the increased heat load associated with continuous exercise. This was felt to cause A-V shunting, reducing the amount of A-V difference and thus lowering the potential for VO$_2$max. It was also found that any particular treadmill time produced a variety of oxygen consumptions and it was felt that this result casts doubt on tests which utilize treadmill time only to evaluate functional status of patients.

Fardy and Hellerstein (1978) compared continuous and intermittent exercises of equal workload for three-minute bouts. They found that oxygen uptake in the first two minutes of the intermittent bout was lower than the continuous bout, but that the difference was diminished as the workload increased. Steady state was reached around the middle of the second minute, and it was felt that this may indicate the possibility of reduced testing time for some tests. The conclusion was that the intermittent test had a slight advantage for testing cardiac function and for exercise prescription.

Implications for Present Study

While comparisons of continuous and discontinuous protocols have yielded fairly close results in the
achievement of maximal readings for oxygen consumption, in general, the discontinuous tests have yielded slightly higher readings (Fardy & Hellerstein, 1978; Maksud & Coutts, 1971; McArdle, Katch & Pecar, 1973). Though the differences have not been marked enough to be statistically significant, the trend has been consistent enough to merit further research. Since in the world of competitive athletes minute differences can be the distinction between success and failure, small trends still bear consideratation.

There has also been some indication that subjects may prefer the discontinuous test and find it less stressful (McArdle, Katch & Pecar, 1973), which may alleviate psychological barriers to the achievement of maximal levels and make subjects less hesitant to return to the laboratory. No previous research in the area of protocol comparison has attempted to evaluate the subject's subjective reactions.

The major reason researchers have recommended the continuous protocols is the time factor. Discontinuous tests take longer and thus use more laboratory equipment and technician time (Fardy & Hellerstein, 1978; Maksud & Coutts, 1971; McArdle, Katch & Pecar, 1973).

The present study was designed to test the feasibility of incorporating some of the advantages of the discontinuous protocol into a continuous test by inserting a break in the procedure before the subjects are required
to perform at maximal levels. No previous studies have addressed the feasibility of a single performance break having an effect similar to discontinuous protocols with a few or many performance breaks. Astrand (1961) has found that it is possible to reach maximal VO₂ levels in two minutes; therefore, if the break were inserted near the end of the test, the subject would still be able to achieve maximum. The break would introduce a physical and mental break at the point where it should be most effective, and the object of this study was to see if the effect is similar to the effect of intermittent protocols in both oxygen consumption and subject preference.
CHAPTER III

RESEARCH METHOD AND DESIGN

The purpose of this investigation was to compare a VO$_2$ max test protocol incorporating a performance break with a continuous protocol. A secondary purpose was to test and compare subjects' preference and reactions to the two protocols.

Included in this chapter are a description of: the selection of subjects, laboratory methods, testing procedures and method of statistical analysis.

Selection of Subjects

Eleven male volunteer subjects were recruited from the track, cross-country and fencing teams at California State University, Northridge, and from local non-collegiate competitive runners. All were regular runners who had maintained consistent training for at least six months prior to testing. They were instructed to avoid training variations during the testing. All subjects were between 19 and 31 years of age, with a mean age of 23.5 years.
Eight of the subjects were college level competitive runners and three were fencers. Subjects were randomly assigned to Group I or Group II. As part of a counter-balance research design, Group I performed the Maksud Protocol first and the Alternate Protocol a week later. Group II performed the Alternate Protocol the first week and the Maksud Protocol the second week.

Orientation of Subjects

Since some subjects had never run on the treadmill, all subjects were required to attend a practice session one week before the initial test to familiarize themselves with the equipment and procedures. In addition, hydrostatic weighing for determination of body fat was performed during this initial visit.

Written instructions for the protocols were handed to the subjects to read and ask questions about when they arrived at the laboratory before each test. Separate written instructions were provided for each protocol. Subjects read the instructions before laboratory technicians attached electrodes to the subject's body and prepared him for the test. Oral instructions only were given for the underwater weighing procedure. Subjects were further orally instructed to avoid changes in eating, sleeping or training habits before and between the tests. An opportunity was given to ask questions to clarify any
part of the test protocol. The total oral and written orientation for each subject was approximately fifteen minutes.

**Laboratory Methods**

Subjects were required to come to the laboratory three times. During the initial visit, percent body fat was determined by underwater weighing and subjects were given a practice session on the treadmill to familiarize themselves with the equipment and procedures. During the practice session, the subject was given a five-minute warm-up at three miles per hour, then the treadmill speed was increased to seven miles per hour and the grade increased by 2.5% every thirty seconds until the end of the third minute, at which time the grade was 12.5%. This familiarized the subject with the experience of running at seven miles per hour on the treadmill, wearing the equipment, and with the uphill running as the grade increased. Subjects who felt especially uncomfortable with any part of the procedure were given more gradual increments in workload. After the run, each subject was allowed to walk at a cool-down pace of three miles per hour until he had been cooled down enough to feel like dismounting. The cool-down period was left to the subject's discretion, because the ease with which they finished the practice session varied, and thus the need for a recovery period
was not the same for all. After the cool-down, the subjects were encouraged to ask any questions about the protocols, the equipment, the procedures, and their relative performance.

On the second visit, the subjects were given written instructions detailing the protocol to be used during the session. Subjects then had electrodes attached and the equipment fitted. They then mounted the treadmill and the test was begun.

On the third visit, subjects were again given written instructions for the appropriate protocol. After reading the instructions, subjects had the electrodes attached, were fitted with the equipment, and mounted the treadmill for the test.

Underwater Weighing

Subjects' percent body fat was determined using underwater weighing to determine body density. This physiological measure was used as an important index for describing the subject population. Subjects were immersed in a densitrometric tank designed by Dr. George Q. Rich III at California State University, Northridge, and equipped with a Chatillon autopsy scale.

Corrections were made for residual lung volume and intestinal gas. Residual lung volume was determined by Wilmore's (1969) method of using vital capacity multi-
plied by .24. Vital capacity was measured by a Collins 13 liter water spirometer. Calculations of body fat and density were based on the equations of Siri (1956) and Behnke and Wilmore (1970) respectively:

\[
\text{Percent Fat} = \frac{4.570}{\text{Db}} - 4.142 \times 100.
\]

\[
\text{Body Density} = \frac{\text{Ma} - \text{Mw} - (\text{RV} + \text{VGI})}{\text{Dw}}
\]

In the preceding formulas:

- \( \text{Ma} \) = Mass in air
- \( \text{Mw} \) = Mass in water
- \( \text{Dw} \) = Water density, corrected for temperature
- \( \text{RV} \) = Residual lung volume
- \( \text{VGI} \) = Volume of gas in intestinal tract

The Treadmill Protocols

Electrodes were attached to the subject for the ECG monitoring of heart rate and for the appearance of any abnormal conduction patterns.

Subjects were informed that they could stop the test at any time they felt unable to continue for any reason. Subjects then mounted the treadmill and were attached to the safety harness to prevent a fall.

A helmet was fitted to the head to support the
breathing apparatus, and the breathing apparatus was then attached to the air gauge and inserted into the subject's mouth.

**The Maksud Protocol**

The treadmill was started with the speed set at 0% grade and three miles per hour. The Maksud Protocol required the subject to walk ten minutes at three miles per hour, and then have the speed raised to seven miles per hour and the grade increased by two-and-a-half degrees per minute until the subject was forced to quit by fatigue. The speed was then decreased to three miles per hour and the grade lowered to 0% for the cool-down walk of five minutes. Heart rate and volume of expired air were recorded each minute and air samples were taken for each minute from the fifth minute onward. When the subject indicated he felt he was in his last minute, readings and air samples were taken every thirty seconds. At exhaustion, the subject straddled the treadmill; the speed and grade were immediately lowered to the cool-down levels.

**The Alternate Protocol**

The Alternate Protocol also required the subject to perform a ten-minute warm-up at three miles per hour and 0% grade. The speed was then increased to seven miles per hour and the grade increased by 2.5% each minute.
When the subject indicated he felt he was into the last minute, the speed was immediately decreased to three miles and the grade decreased to zero for a two-minute walking break. At the end of the break, the speed was raised to nine miles per hour and the grade raised to 2.5% higher than the grade at the point before the break. The subject then ran for ninety to one hundred twenty seconds at the new speed and grade until forced to quit by exhaustion. Readings and air samples were taken every thirty seconds after the break. Before the break, readings and air samples were taken each minute from the fifth minute onward, as in the Maksud Protocol.

The increased speed after the break was designed to raise performance levels in a manner similar to the free speed ending on the bike ergometer tests (Bell & Ribisl, 1980).

The Questionnaire

The questionnaire was designed to evaluate the subject's overall subjective reaction to the two protocols. Designed by the experimenter, it included questions on the equipment, the protocol and subject preference for either of the two laboratory protocols. Subjects filled out the questionnaire immediately after the completion of each protocol to make sure all reactions were fresh and that the time sequence was the same for both tests.
No discussion with the laboratory technicians occurred during the time the questionnaire was being filled out. Discussion of the questionnaire was avoided to reduce the possibility of influencing the subject's response.

**Instrumentation**

The experiment was performed on a recently calibrated Quinton treadmill, Model 24-72, driven by a five horsepower motor with adjustable speed and grade. The built-in speedometer is accurate to within one-half mile per hour.

The safety harness was a Nissen gymnastics spotting belt attached to a nylon rope on a pulley to allow adjustment to individual subjects. All subjects wore the belt during all performances on the treadmill.

Ventilation was collected by a Collins Triple J one-way breathing apparatus with a Collins #530 mouth-piece, and measured through a Parkinson-Cowen #DC4 Gasometer in liters and milliliters. The breathing apparatus was supported by a Huntsman helmet. Subjects wore a Collins sponge rubber nose clip. A three-lead Hewlett Packard #7803A ECG was used to measure heart rate and to monitor conduction patterns. If abnormal patterns were observed in any subject, the laboratory technicians were instructed to immediately halt the test. Air samples were
collected with 50cc glass syringes, sealed with mineral oil. Air samples were analyzed by an I-L Polarigraph #326. Three measures of oxygen and carbon dioxide percentages were done on each air sample to assure accuracy.
ANALYSIS OF THE DATA

The purpose of this study was to measure and compare the VO₂ values obtained on subjects tested, using a standard uninterrupted protocol with those using a protocol which incorporated a two-minute performance break. A further purpose was to determine subject's subjective preference for one protocol or the other.

Following the collection of the laboratory data, the means of the VO₂ max for the two protocols were compared using a t-test. Correlations were determined to compare the relationship between the protocols, and between the first and second test performed by each subject regardless of protocol.

Height, weight and body composition were measured for each subject to further describe the population of endurance trained subjects.

A questionnaire was administered to each subject in order to compare the subjective reactions to the two protocols. The questionnaire included seven questions; five were objective and two were open-ended, allowing the
subjects to express their feelings in their own words.
To determine the mean difference between subject reactions to the two protocols, t-tests were administered for each of the objective questions. The subjective answers were examined individually and appear in the discussion section of Chapter V.

Table I displays the descriptive physiological parameters for the eleven subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Height</th>
<th>Body Mass</th>
<th>Lean</th>
<th>Fat</th>
<th>Percent Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.M.</td>
<td>24</td>
<td>1.85</td>
<td>66.0</td>
<td>56.6</td>
<td>9.4</td>
<td>14.3</td>
</tr>
<tr>
<td>A.T.</td>
<td>24</td>
<td>1.82</td>
<td>70.5</td>
<td>59.6</td>
<td>10.1</td>
<td>15.5</td>
</tr>
<tr>
<td>A.F.</td>
<td>24</td>
<td>1.70</td>
<td>60.0</td>
<td>53.6</td>
<td>6.4</td>
<td>10.6</td>
</tr>
<tr>
<td>D.S.</td>
<td>26</td>
<td>1.78</td>
<td>67.1</td>
<td>61.9</td>
<td>5.2</td>
<td>7.8</td>
</tr>
<tr>
<td>D.F.</td>
<td>31</td>
<td>1.85</td>
<td>66.8</td>
<td>58.1</td>
<td>8.7</td>
<td>13.1</td>
</tr>
<tr>
<td>T.H.</td>
<td>27</td>
<td>1.80</td>
<td>70.9</td>
<td>62.9</td>
<td>8.0</td>
<td>11.3</td>
</tr>
<tr>
<td>F.C.</td>
<td>22</td>
<td>1.78</td>
<td>83.2</td>
<td>71.1</td>
<td>12.1</td>
<td>14.5</td>
</tr>
<tr>
<td>T.O.</td>
<td>19</td>
<td>1.75</td>
<td>62.7</td>
<td>57.6</td>
<td>5.1</td>
<td>8.2</td>
</tr>
<tr>
<td>L.D.</td>
<td>21</td>
<td>1.80</td>
<td>73.6</td>
<td>62.5</td>
<td>11.1</td>
<td>14.5</td>
</tr>
<tr>
<td>R.S.</td>
<td>24</td>
<td>1.73</td>
<td>62.2</td>
<td>55.5</td>
<td>6.5</td>
<td>10.4</td>
</tr>
<tr>
<td>T.B.</td>
<td>23</td>
<td>1.80</td>
<td>71.3</td>
<td>64.4</td>
<td>6.9</td>
<td>9.7</td>
</tr>
<tr>
<td>Mean</td>
<td>24.1</td>
<td>1.79</td>
<td>68.5</td>
<td>60.4</td>
<td>8.1</td>
<td>11.8</td>
</tr>
</tbody>
</table>
The subjects were well-trained young endurance runners with a mean age of twenty-four years. Mean height and weight for the group was 1.79 meters and 68.5 kilograms. Mean body fat was 11.8 percent.

Table II shows the peak performance data of each subject on both the Maksud Protocol and the Alternate Protocol. Heart rate, pulmonary ventilation and \( VO_2 \) max are included for each subject.

### TABLE II

<table>
<thead>
<tr>
<th>Subject</th>
<th>Maksud Protocol</th>
<th>Alternate Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>Vent</td>
</tr>
<tr>
<td>S.M.</td>
<td>200</td>
<td>111.3</td>
</tr>
<tr>
<td>A.T.</td>
<td>198</td>
<td>120.8</td>
</tr>
<tr>
<td>A.F.</td>
<td>201</td>
<td>96.0</td>
</tr>
<tr>
<td>D.S.</td>
<td>197</td>
<td>128.2</td>
</tr>
<tr>
<td>C.F.</td>
<td>200</td>
<td>129.9</td>
</tr>
<tr>
<td>T.H.</td>
<td>198</td>
<td>115.8</td>
</tr>
<tr>
<td>F.C.</td>
<td>191</td>
<td>115.0</td>
</tr>
<tr>
<td>T.O.</td>
<td>190</td>
<td>124.5</td>
</tr>
<tr>
<td>L.D.</td>
<td>185</td>
<td>97.5</td>
</tr>
<tr>
<td>R.S.</td>
<td>200</td>
<td>115.9</td>
</tr>
<tr>
<td>T.B.</td>
<td>198</td>
<td>111.8</td>
</tr>
</tbody>
</table>

Mean 196.2 115.1 60.26 196.8 118.2 61.14
HR = Heart rate in beats per minute.
Vent = Pulmonary ventilation in liters per minute.
VO₂ = Peak oxygen consumption in milliliters of oxygen per kilogram of body weight per minute.

Mean VO₂ max was 60.26 ml/kg/min and 61.14 ml/kg/min for the Maksud Protocol and the Alternate Protocol respectively. Mean peak pulmonary ventilation was 115.1 milliliters per minute during the Maksud Protocol and 118.2 milliliters per minute during the Alternate Protocol. Mean peak heart rates were 196.8 and 196.2 beats per minute for the Alternate Protocol and the Maksud Protocol respectively.

Table III shows a comparison of mean peak performance data for the Maksud Protocol and the Alternate Protocol. Means are compared using a t-test and a correlation coefficient.

**TABLE III**

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Mean VO₂</th>
<th>SD</th>
<th>t-test</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maksud</td>
<td>60.26 ml/kg/min</td>
<td>8.96</td>
<td>t=.071</td>
<td>r=.856</td>
</tr>
<tr>
<td>Alternate</td>
<td>61.14 ml/kg/min</td>
<td>8.45</td>
<td>P&gt;.05</td>
<td>P&lt;.05</td>
</tr>
</tbody>
</table>

Mean difference = 0.88 ml

df = 10
The mean VO₂max of the Alternate Protocol was slightly higher than the mean VO₂ of the Maksud Protocol. The small observed mean difference was not significant at the .05 level (t=.071) and therefore is not considered to be a true difference. The mean VO₂max of the two protocols had a significant positive correlation of r=.856.

Table V displays a comparison of test sequence and peak performance. The first test administered to each subject was compared with the second test administered regardless of protocol.

TABLE IV
A COMPARISON OF TEST ADMINISTRATION SEQUENCE AND MEAN PEAK PERFORMANCE DATA

<table>
<thead>
<tr>
<th>Test Sequence</th>
<th>t-test</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>First test 61.00 ml/kg/min</td>
<td>8.90</td>
<td>t=.045 r=.852</td>
</tr>
<tr>
<td>Second test 60.44 ml/kg/min</td>
<td>8.54</td>
<td>p&gt;.05 p&lt;.05</td>
</tr>
</tbody>
</table>

Mean difference = 0.56 ml

df = 10
The mean \( \text{VO}_2\text{max} \) difference between the first test administered and the second test was 0.56 ml. This difference was not significant at the .05 level of confidence (\( P > .05 \)). The mean \( \text{VO}_2\text{max} \) for the first protocol had a significant positive correlation with the second protocol (\( P < .05 \)).

The response of each subject to the five objective questions in the questionnaire are shown in Table VI. The mean of the responses to each question is also shown. The five objective questions were answered according to the following scale: one = strongly agree; two = agree; three = neutral; four = disagree; and five = strongly disagree.

A t-test was performed on each mean response to the five objective questions. None of the mean responses to the five questions was significantly different for the two protocols at the .05 level of confidence, \( t = .098, .145, 0, .047 \) and .196 for the five responses respectively. No subject preference for one protocol or the other was indicated by the responses to the five questions.

Since the two subjective questions were not quantifiable, they are discussed individually in the fifth chapter. The responses to the subjective questions are displayed in the appendix.
TABLE V
SUBJECT RESPONSES TO THE QUESTIONNAIRE

<table>
<thead>
<tr>
<th>Question #</th>
<th>one</th>
<th>two</th>
<th>three</th>
<th>four</th>
<th>five</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maksud Protocol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.S.</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>T.B.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>L.D.</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>T.O.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>F.C.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C.F.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>T.H.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>D.S.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>A.F.</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>S.M.</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>1.45</td>
<td>1.18</td>
<td>1.45</td>
<td>2.73</td>
<td>4.00</td>
</tr>
<tr>
<td><strong>Alternate Protocol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.S.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>T.B.</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>L.D.</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>T.O.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>F.C.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>C.F.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>T.H.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>D.S.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>A.F.</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>S.M.</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>1.54</td>
<td>1.27</td>
<td>1.45</td>
<td>2.81</td>
<td>3.73</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION OF THE FINDINGS

The eleven subjects used in this study each performed two maximal VO\textsubscript{2} tests on two motor-driven treadmill ergometers. The elapsed time between the two test administrations was one week. The order in which the protocols were performed was randomly assigned. Six subjects started with the Maksud Protocol and performed the Alternate Protocol one week later. Five subjects performed the Alternate Protocol first and the Maksud Protocol one week later. Immediately following the performance of each laboratory test, the subjects completed a questionnaire designed to test their subjective reactions to the protocol.

Height, weight and body composition were determined for each subject. Table I shows the descriptive results of these measurements. The mean percent body fat for this group of endurance trained subjects was slightly higher (11.8\%) than those recorded by investigators for similar endurance trained subjects (Costill, 1967, 1978, 1979; Hagerman & Howie, 1971; Poolack, 1978). This may
have been due to the fact that not all subjects in this study were competitive distance runners; two ran as conditioning for fencing (30 to 35 miles per week) and two were relative beginners at distance running, having competed for less than one year.

Comparison of the Two Protocols

The mean recordings of VO$_2$max for the Maksud Protocol were not significantly different than those recorded for the Alternate Protocol ($t=.071$) by the same subjects. Thus, the null hypothesis of no significant difference between the means was supported. Therefore, it was concluded that a two-minute performance break inserted into a continuous work protocol does not affect the resulting measurement of VO$_2$max. This finding is corroborated by other studies that compared continuous and discontinuous protocols of various designs without finding significant differences (Fardy & Hellerstein, 1978; Froelicher, Brommell, Davis, Noguera, Stewart & Lancaster, 1974; Maksud & Coutts, 1971; McArdle, Katch & Pecah, 1973).

The mean of the Alternate Protocol was slightly higher than the mean of the Maksud Protocol. These non-significant results may be compared to the findings of other researchers who have recorded no significant differences in VO$_2$max measurements for intermittent protocols when compared with continuous protocols (Fardy & Pechar,
The means of the two protocols had a significant positive correlation ($r=0.856$), indicating consistency of results.

The mean of the first test administered to each subject was compared with the mean of the second test, regardless of protocol. This analysis was necessary to determine whether any possible training effects occurred, because half of the subjects were first administered the Maksud Protocol and the other half started with the Alternate Protocol. There was no significant difference at the 0.05 level of confidence between the means of the first and second tests administered ($t=0.045$). The first and second tests had a high positive correlation ($r=0.852$), indicating that a one-week break between maximal oxygen uptake tests is sufficient time for subjects to recover adequately to perform a second maximum test. This finding is corroborated by the findings of Stamford, Weltman, Moffott and Fulco (1978) which indicate that fit young subjects are able to perform to maximum levels even when moderately fatigued.

Since the Alternate Protocol requires more laboratory time and more highly-specialized training of laboratory personnel, yet yields results that are not significantly different than the uninterrupted Maksud Protocol, adherence to the more traditional test format is
indicated. This conclusion replicated the recommendations of other researchers who have compared continuous and discontinuous protocols (Hermansen & Saltin, 1969; Maksud & Coutts, 1971).

The Questionnaire

After each test, the subjects immediately completed the required questionnaire. Five objective questions and two subjective questions were used (Appendix A). Questions one through five were answered using the key described in Chapter IV.

No previous study has attempted to assess subject preference for a specific type of protocol. McArdle, Katch and Pechar (1973) indicated there was slight subject preference for a discontinuous protocol, but made no effort to specify the information resulting in this conclusion. Thus, there is no precedent for the inclusion of an assessment of subject preference.

Question one was, "I felt I was able to achieve maximum effort during this test." The mean answer to this question for the Maksud Protocol was 1.45, while the mean for the Alternate Protocol was 1.54. This was not a significant mean difference at the .05 level of confidence (t=.098). The answers indicate that the subjects were of the opinion that they were able to produce maximum efforts under both test conditions.
Question two was, "I clearly understood what to do and what to expect during the test." This question was designed to investigate the possibility of the performance break in the Alternate Protocol producing confusion or disorientation among the subjects. The mean answers, 1.18 for the Maksud Protocol and 1.27 for the Alternate Protocol, indicated that the added factor of a performance break did not cause subject confusion since the mean difference was not significant at the .05 level of confidence (t=.145). The low score for both tests indicated that subjects were clearly aware of the proceedings and of their test role at all times.

Question three was, "I was highly motivated to reach maximum effort." No motivational difference among the subjects was indicated between the protocols since the means were identical (P> .05). This mean score of 1.45 indicated high motivation among the subjects for both protocols.

Question four was designed to explore the possibility of differences in physical discomfort between the two protocols. No difference in the perceived discomfort levels for the two protocols was demonstrated (P>.05). A list of possible physical discomforts was included with a place to check those which might be applicable. Four subjects indicated they experienced leg fatigue during both tests, which presumably reflected the
"uphill" nature of the treadmill tests but did not distinguish between the two protocols.

Question five was, "I experienced discomfort due to the equipment or procedures." Again, there was no significant difference between the mean answers to the question for the Maksud and the Alternate Protocols (t=.196). The mean responses of 4.0 and 3.73 for the Maksud and Alternate Protocols respectively appeared to indicate that the subjects were reasonably comfortable with both test proceedings.

Question six was open-ended. Subjects were asked for "general comments, feelings and recommendations". Three subjects commented about their desire to work harder or improve their physical condition. Three subjects commented about the procedures, the laboratory technicians and the experiments. These comments were generally favorable. Two subjects complained of throat dryness from the breathing apparatus. One subject expressed a desire to be able to perform the test without the pulmonary monitoring equipment or the electrodes used to monitor cardiac function. This question was designed to provide the experimenter with subjective feedback concerning laboratory procedures. Most subjects made similar comments regarding both protocols. Specific answers to the open-ended questions appear in Appendix D.

The seventh question asked the subjects to com-
pare the protocols in their own words. Two subjects expressed the belief that the two protocols were the same. The others were divided on which protocol they felt was more difficult. Three subjects stated that they felt the Maksud Protocol was easier. One subject indicated that the higher speed at the end of the Alternate Protocol was distressful to the large muscles of the lower extremity. Four of the subjects expressed the view that the Alternate Protocol was physically less taxing than the Maksud Protocol. Two subjects stated that they were able to achieve higher results with the Alternate Protocol. Both of these subjects recorded higher readings for the Alternate Protocol (62 ml/kg/min to 58 ml/kg/min and 49 ml/kg/min to 48 ml/kg/min respectively). From the above analysis, it was concluded that the seventh question failed to distinguish between the two protocols. Although individuals showed preferences for one protocol or the other, they were divided on which they preferred. Question seven did, however, show that the subjects felt more comfortable the second time they performed a maximum test, regardless of protocol.

The results of the questionnaire, both the objective and the subjective portions, revealed no apparent differences between subject preference for a protocol that incorporates a performance break and a continuous protocol. Thus, economic use of laboratory
time and equipment and ease of test administration would indicate adherence to the continuous Maksud Protocol.

Summary of Major Findings

1. A group of eleven subjects performed the Maksud Protocol and the Alternate Protocol. No significant difference was found between the mean VO₂ measurements obtained by the two methods.

2. No significant difference or clear preference was shown in subject reactions to the two protocols as indicated by subject answers to five objective questions and two subjective, open-ended questions.

3. The mean difference between the first test administered to each subject and the second test, regardless of protocol, was not found to be significant.

4. Since there was a high correlation between the first test administered to each subject and the second test, it was concluded that one week is adequate recovery time between maximum VO₂ tests for endurance trained subjects.
CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter includes the organization and summary of the data from the preceding chapter.

Summary

The purpose of the study was to determine if the insertion of a performance break into a continuous protocol for testing VO₂max would enable subjects to achieve higher VO₂max recordings. A further purpose was to determine subjects' reactions to a protocol with a performance break as compared with subject reaction to an uninterrupted protocol.

Eleven endurance trained subjects were tested on a continuous protocol described by Maksud and Coutts (1971) and an Alternate Protocol that incorporated a two-minute performance break before the final two minutes of maximum effort. The Alternate Protocol and the Maksud Protocol were administered with a seven-day interval between the performance of the first test and the performance of the second.
Subjects filled out a questionnaire which consisted of five objective questions and two open-ended questions. The questionnaire was filled out at the conclusion of each protocol. The questions were designed to determine subjects' reactions to the two protocols and to determine if subjects had a performance preference for one protocol or the other.

At the conclusion of the study, data was analyzed using a t-test to compare means of VO\textsubscript{2}\text{max} measurements for the protocols. Correlations were also determined between the subjects' performance on the two protocols. An additional correlation was determined between the first and the second tests performed, regardless of protocol.

The answers to the objective portion of the questionnaire were analyzed to determine mean differences between the answer to a specific question for the Maksud Protocol and the answer to the same question for the Alternate Protocol. The subjective answers were analyzed with respect to individual responses.

**Conclusion**

No significant difference was indicated between the Maksud Protocol and the Alternate Protocol. It was concluded that the insertion of a performance break into a continuous protocol does not significantly affect the
resulting measurement of VO$_2$max.

No significant differences in subjects' reaction were determined by either the subjective or the objective portions of the questionnaire. It was concluded that the insertion of a performance break into a continuous protocol has no effect on subjects' reaction or subject preference.

Recommendations

From the analysis and interpretation of the data from the present study, the following recommendations are made:

1. A treadmill test to determine VO$_2$max with a performance break or a discontinuous protocol, utilizing untrained subjects rather than endurance trained subjects may yield different results.

2. A treadmill test of VO$_2$max to determine the effects of micro pauses in performance (10 seconds or less) may influence subject's VO$_2$max measurements.

3. An oxygen uptake test to determine if performance breaks affect VO$_2$max tests performed on the bicycle ergometer, the laddermill or other tests where localized fatigue is a limiting factor, might yield significant findings.
4. A treadmill test of VO₂ to determine if a performance break or performance breaks during maximum or sub-maximum tests of aerobic power might reduce the danger to heart patients or others who must be closely monitored while undergoing physical tests might prove significant.

5. An intermittent VO₂ max test using heart rate instead of time to monitor the amount of rest, might show significance.
BIBLIOGRAPHY

Books


Periodicals


Gleser, M.A. The effect of VO2 max of adding arm work to maximal leg work. Medicine and Science in Sports. 1974, 6, 104-107.


Pollack, M. Cream of the crop. Marathoner. 1978, 1, 115-121.


APPENDIX A

SUBJECT QUESTIONNAIRE
SUBJECT QUESTIONNAIRE

Test 1st ( ) 2nd ( ) Protocol______________ Date__________
Name_________________________ Age______ VO₂__________

Key = 1-Strongly agree; 2-agree; 3-neutral; 4-disagree; 5-strongly disagree

Please circle the number that best corresponds with your answer using the above key.

1. I felt I was able to achieve maximum effort during this test. 1 2 3 4 5

2. I clearly understood what to do and what to expect during this test. 1 2 3 4 5

3. I was highly motivated to reach maximum effort. 1 2 3 4 5

4. I experienced physical discomfort during the test due to the level of work achieved. 1 2 3 4 5
   If so, please indicate the type of discomfort you felt:
   ( ) Leg fatigue
   ( ) Pain or pressure in chest, arm or throat
   ( ) Nausea or vomiting
   ( ) Extreme breathlessness for more than ten minutes after the exercise
   ( ) Shin splints (pain in front or side of lower leg)
   ( ) Side ache
   ( ) Muscle cramp or "charlie horse"
   ( ) Pain in a specific area or muscle.
   Which? ________________________________
   ( ) Other ________________________________

5. I experienced discomfort due to laboratory equipment or procedures. 1 2 3 4 5

6. Please give any general comments, feelings or recommendations.

7. (after second test) How do you feel about this test as compared with your first trial?
APPENDIX B

INSTRUCTIONS FOR SUBJECTS

Maksud Protocol
Alternate Protocol
INSTRUCTIONS FOR SUBJECTS (Maksud Protocol)

Thank you for participating in this study. The purpose of this experiment is to determine the best protocol to follow when measuring maximum oxygen uptake in fit subjects.

During the procedure, you will wear electrodes which will give us a running account of your heart rate and monitor your heart's electrical impulses.

You will have a nose clip and wear breathing apparatus that will direct your air through a meter which will measure your expired air and be used to calculate your oxygen uptake. The apparatus will be supported by a helmet and a cord. Any discomfort or displacement can be pointed out to the operators by indicating the trouble area with your right hand.

THE PROCEDURE

You will walk for ten minutes at 3.5 miles per hour to warm up and get accustomed to the treadmill. During the seventh minute, the speed will be increased to 7 miles per hour. You will run at 7 miles per hour for the remainder of the session.

At the end of each minute, the grade will be increased by 2.5%. You will thus be running up an ever-steeper grade throughout the test. When you feel you have
one minute left in you -- meaning you can continue for one more minute, but not two minutes -- signal the operator by raising your left index finger. If you have any problems, use your right hand to indicate the source.

When you are told the last minute is over, grasp the hand rails and straddle the mill, making sure your feet clear the belt. The speed and grade will be immediately lowered to walking speed for your cool-down. When given the word, you should remount the mill and walk at the cool-down speed for several minutes.

Please be sure to fill out the short questionnaire before you leave.

Thank you again for participating in the study.
INSTRUCTIONS FOR SUBJECTS (Alternate Protocol)

Thank you for participating in this study. The purpose of this experiment is to determine the best protocol to follow when measuring maximum oxygen uptake in fit subjects.

During the procedure, you will wear electrodes which will give us a running account of your heart rate and monitor your heart's electrical impulses.

You will have a nose clip and wear breathing apparatus that will direct your air through a meter which will measure your expired air and be used to calculate your oxygen uptake. The apparatus will be supported by a helmet and a cord. Any discomfort or displacement can be pointed out to the operators by indicating the trouble area with your right hand.

THE PROCEDURE

You will walk for ten minutes at 3.5 miles per hour to warm up and become accustomed to the treadmill. During the seventh minute, the speed will be increased to seven miles per hour. Hereafter, at the end of each minute, the grade will be increased by 2.5%. You will thus be running up an ever-steeper grade throughout the test.

When you feel you have one minute left in you --
meaning you can continue for one more minute, but not two minutes -- signal the mill operator by raising your left index finger. If any problems occur with the equipment, etc., you may indicate the problem area with your right hand.

When you signal, the speed and grade will be immediately slowed and lowered to 3 miles per hour and 0% grade for two minutes' rest.

After the two minutes' rest, the speed will be increased to nine miles per hour and the grade increased 2.5% higher than the previous level. When you feel that you can continue for one more minute at the new work level, again signal with the left index finger.

When the last minute has ended, grasp both hand rails with a firm grasp and straddle the mill, making sure your feet clear the belt. The speed and grade will be lowered to walking speed and you will be able to walk at a lower speed to cool down.

Please be sure to fill out the short questionnaire before you leave.

Thank you again for participating in this study.
APPENDIX D

SUBJECTIVE QUESTION RESPONSES
SUBJECTS' RESPONSES TO QUESTION 6:
"PLEASE GIVE ANY GENERAL COMMENTS, FEELINGS OR RECOMMENDATIONS."

<table>
<thead>
<tr>
<th>Subject</th>
<th>Re: Maksud Protocol</th>
<th>Re: Alternate Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM</td>
<td>I was very tired and felt like I was going to get sick, but didn't. I felt slow when I ran and very fatigued. I felt my leg muscles more on this test.</td>
<td>My throat was very dry.</td>
</tr>
<tr>
<td>RF</td>
<td>Good test. Felt very confident with the procedure and Bob.</td>
<td>I felt I reached a higher level of work due to the fact that I was more familiar with the equipment this time.</td>
</tr>
<tr>
<td>ET</td>
<td>For myself, need to push.</td>
<td>----</td>
</tr>
<tr>
<td>TH</td>
<td>----</td>
<td>Felt like I could do more.</td>
</tr>
<tr>
<td>FC</td>
<td>I felt a little discomfort breathing through the tube.</td>
<td>I felt as if I need to get in shape. Although the time period was short, the energy expended seemed equivalent to running hard when jogging for a long period of time or two hours of handball.</td>
</tr>
<tr>
<td>LD</td>
<td>----</td>
<td>The test was conducted in a very professional and orderly manner.</td>
</tr>
<tr>
<td>AF</td>
<td>Get rid of head gear, breathing apparatus; use electrodes that do not require abrading.</td>
<td>----</td>
</tr>
<tr>
<td>TO</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>TB</td>
<td>Never having done a maximum test, it was a fun, interesting experience.</td>
<td>This protocol felt like I had pushed my legs to their max, but not my cardio vascular system.</td>
</tr>
<tr>
<td>Subject</td>
<td>Re: Maksud Protocol</td>
<td>Re: Alternate Protocol</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>TB</td>
<td>(cont.)</td>
<td>This was due to the 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m.p.h. speed combined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with the increased grade.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Had the speed, grade or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>both been decreased, I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>know I would have con-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tinued longer.</td>
</tr>
<tr>
<td>CF</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>DF</td>
<td>Seemed harder.</td>
<td>Fun to run.</td>
</tr>
</tbody>
</table>
SUBJECTS' RESPONSES TO QUESTION 7:
"(AFTER SECOND TEST) HOW DO YOU FEEL ABOUT THIS TEST AS COMPARED WITH YOUR FIRST TRIAL?"

<table>
<thead>
<tr>
<th>Subject</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM</td>
<td>I knew more of what to expect. I did not reach as high a heart rate because I was still recovering from the first test.</td>
</tr>
<tr>
<td>RF</td>
<td>I was able to achieve a higher work load with the Alternate Protocol due to the rest.</td>
</tr>
<tr>
<td>AT</td>
<td>The test seemed easier.</td>
</tr>
<tr>
<td>TH</td>
<td>Maksud seemed harder.</td>
</tr>
<tr>
<td>FC</td>
<td>The second test (Alternate) seemed easier than the first. It seemed that the rest enabled me to work harder.</td>
</tr>
<tr>
<td>LD</td>
<td>The Maksud test was not as hard as the first test.</td>
</tr>
<tr>
<td>AF</td>
<td>Both were hard, but I was more familiar with the test after finishing the first trial, and that helped my second effort.</td>
</tr>
<tr>
<td>TO</td>
<td>I felt that both tests were the same because I gave maximum effort both times.</td>
</tr>
<tr>
<td>TB</td>
<td>I felt my recovery time was decreased in the Alternate Protocol, as was the initial level of fatigue at completion of the test.</td>
</tr>
<tr>
<td>CF</td>
<td>Both tests seemed equally demanding.</td>
</tr>
<tr>
<td>DF</td>
<td>About the same.</td>
</tr>
</tbody>
</table>