To the Graduate Council:

I am submitting herewith a thesis written by Sandra Hewitt Clark entitled "Caloric Cost of Running During Workouts of Moderate and High Intensities in Men and Women." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Physical Education.

B. Don Franks

B. Don Franks, Major Professor

We have read this thesis and recommend its acceptance:

Thomas S. Crowan III

Jean Leiser

Accepted for the Council:

CW Minkel

The Graduate School

CALORIC COST OF RUNNING DURING WORKOUTS OF MODERATE AND HIGH INTENSITIES IN MEN AND WOMEN

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Sandra Hewitt Clark

August 1984

Dedicated to

My husband, Bruce

for his support, patience, and tolerance

ACKNOWLEDGEMENTS

I would like to express my thanks and appreciation to the many individuals who helped make possible the completion of this project. A special thanks to:

Dr. B. Don Franks, my major professor, for his guidance, encouragement, and unlimited time that he gave me throughout the past year. His enthusiasm and humor made the experience much less frustrating;

Dr. Tom Cronan and Dr. Jean Lewis, for serving on my thesis committee. Their support and influence in the recruitment of subjects for the project was greatly appreciated;

Wendy Bubb, who provided the original idea for this study. Her time and technical assistance which she gave to me was invaluable;

Jerri Cable, who generously gave her time and assistance with the treadmill tests;

Jackie Reed, Pat Van Rossum, Jay Stanhope, Lisa Edgin, Doug Salmon, Valerie Privett, Amy Mays, and Tim Lightfoot, for giving their time and efforts during the completion of this project;

Randy Claytor, Dr. Glen Brice, and Pam Andrews who came to my aid numerous times concerning the lab equipment and procedures;

Mary Lou Hewitt, my mother, and Blanche Johnstone, my aunt, who came from Oklahoma and assisted me with many treadmill tests;

Bruce Clark, my husband, who came to my rescue with his knowledge of computer programming.

ABSTRACT

This study determined the differences in caloric expenditure between moderate and high intensity workouts with respect to gender. Five males and five females volunteered to be subjects for the treadmill testing. The procedures for each subject consisted of: (1) an accommodation period to become familiar with the equipment and protocols; (2) a maximal oxygen uptake test; (3) a moderate continuous two mile workout; and (4) a high intermittent two mile workout. The moderate and high intensity workout speeds were calculated to correspond to 60 and 90% of max $\dot{V}O_2$. Expired gas samples were taken during a five minute baseline walk, the two mile workout, and a 12 minute recovery walk. Caloric cost for the two mile workout and recovery was calculated using oxygen uptake (L/min) and the caloric equivalent for one liter O_2 (based on R value). The high intensity intermittent workout required a significantly greater number of calories than the moderate intensity continuous workout for both males and females ($p < .001$). The males expended a significantly ($p < .001$) greater total calories although there were no significant differences found in the caloric cost/kg between males and females. Within the limits of the study, it is concluded that high intensity running has higher caloric cost when expressed both in the total calories and kcal/kg than moderate intensity running. Therefore, a person running at a high intensity would lose weight at a greater rate than running at a moderate intensity, assuming all other weight control variables are held constant.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

For many years caloric restriction was the main prescription for weight loss. Studies reported by Greene (1939), Johnson, Burke, and Mayer (1956), Chirico and Stunkard (1960), and Mayer and Thomas (1967) indicated that overweight individuals do no necessarily eat more than those with normal weight but that they may be less active. Therefore, the American College of Sports Medicine (1983), and others (Oscai, 1973; Zuti & Golding, 1967; Franklin & Rubinfire, 1980), recommend exercise therapy along with caloric restriction as an effective regimen for altering body weight.

Questions have arisen as to the type of exercise which should be recommended, and the duration and intensity of the exercise necessary to alter body weight. The general recommendation for the purpose of losing weight is to engage in exercise of long duration, using large muscle groups, and aerobic in nature (Franklin & Rubinfire, 1980; Fox & Mathews, 1981). With endurance-type training programs, total body mass and fat weight are generally reduced while lean body weight remains constant or may show slight increases (American College of Sports Medicine, 1978).

High intensity anaerobic work is less efficient than steady-state aerobic work. The efficiency of the anaerobic contribution to the energy cost of work is in the range of 10-12% (Asmussen, 1946) while values for the efficiency of low intensity steady-state exercise have been reported to be in the range of 24-34% (Whipp & Wasserman, 1969; Gaesser & Brooks, 1975). Therefore, one might expect to observe an average difference of 14-22% in terms of caloric expenditure between exercise at low and high intensity.

In addition to efficiency, gender may affect caloric cost at different exercise intensities. There is controversy between gender studies (Howley & Glover, 1974; Falls & Humphreys, 1976) as to the caloric expenditure differences between males and females.

The purpose of this investigation was to study the differences in caloric expenditure between moderate and high intensity workouts with respect to gender. The intent of this research was to determine if another approach to weight reduction might be justified.

CHAPTER II

REVIEW OF RELATED LITERATURE

With the popularity of walking and running as modes of exercise, several studies have been conducted to estimate the oxygen and caloric cost of these activities. Various influences on running such as speed, efficiency, and gender differences have been investigated and found to have an effect on the caloric expenditure.

I. PHYSIOLOGICAL EVENTS OF PROGRESSIVE EXERCISE

Skinner and McLellan (1980) identified three phases during the progression from low intensity to maximal intensity exercise. Phase 1 was a low intensity level--below 40% maximal oxygen uptake (max $\dot{V}O_2$). Within this phase, a greater amount of oxygen was extracted by the tissues as intensity increased which resulted in a low fraction of oxygen in the expired air (FeO_2). More CO_2 was produced and expired CO_2 ($FeCO_2$) increased. The respiratory exchange ratio (R) values were found to be within 0.70 to 0.80 range. Phase II was between 40% and 60% of max $\dot{V}O_2$. An increased production of CO_2 and a rise in $FeCO_2$ were noted. Blood lactate increased to twice that of the resting values. The increase of CO_2 and blood lactate was shown to stimulate a higher ventilatory (VE) rate. Increase of ($\dot{V}CO_2$) was greater than the rise of $\dot{V}O_2$ giving an increase in the R value. Phase III occurred with intensities greater than 60% of max $\dot{V}O_2$. Maximal oxygen uptake and heart rate continued to increase linearly until near maximal work loads, at which time a plateau effect was reached. Blood lactate increased rapidly resulting in further increases of VE and $\dot{V}CO_2$. More $\dot{V}O_2$ was being used by the respiratory muscles to take care of the hyperventilation.

As the physical work increased, a progressively greater amount of energy was produced by the anaerobic breakdown of glycogen in the muscles. Lactic acid production and oxidation was indicated by R of 1.0 (Consolzio & Johnson, 1971). Lusk (1928) and Richardson (1929) were among several who published caloric value tables for the R value. The range of R values have been established to be 0.70-1.0. The lower values indicate that fat is the major foodstuff being utilized as a source of energy and that 4.686 calories are expended per liter O_2 consumed (Fox & Mathews, 1981). Higher values indicate carbohydrate is the primary energy source with 5.047 calories expended per liter O_2 consumed (Fox & Mathews, 1981). Values between 0.70 and 1.0 indicate that a mixture of fats and carbohydrates was used for energy during exercise.

II. INTERMITTENT AND CONTINUOUS EXERCISE

A frequently discussed topic is whether physical training is more beneficial when it is completed by either a continuous or an intermittent mode. The intermittent mode is referred to intense exercise followed by periods of rest or mild exercise (Astrand & Rodahl, 1977). Astrand, Astrand, Christensen, and Redman (1960) and Christensen, Hedman, and Saltin (1960) have researched physiological effects of continuous and intermittent type work. Results from these studies were summarized by Astrand and Rodahl (1977).

> A series of studies have shown that maximal oxygen uptake (and cardiac output) may be attained in connection with repeated periods of work of very high intensity of as short duration as 10 to 15 s, provided the rest periods between each burst of activity are very short (of equal or shorter duration than the work periods). In more prolonged work of several minutes duration, the duration of the rest periods is less critical. If the work periods exceed about 10 min. or so, a high level of motivation is required in order to attain maximal oxygen uptakes. In the case of continuous work, the high tempo required for the severe taxation of the oxygen-transporting system must alternate with periods of reduced tempo.
>
> With very short work periods of about 30 s or less, a very severe load may be imposed upon both muscles and oxygen-transporting organs without the engagement of anaerobic processes leading to any significant elevation of the blood lactate. It is thus possible to select the proper work load and work and rest periods in such a manner that the main demand is centered on (1) muscle strength without a major increase in the total oxygen uptake; (2) aerobic processes without significantly mobilizing anaerobic processes; (3) anaerobic processes without maximal taxation of the oxygen-transporting organs; and (4) both aerobic and anaerobic processes simultaneously. (p. 401)

It is known that the length of time one can sustain an exercise activity is dependent on the intensity in which it is performed. A study by Astrand et al. (1960) indicated that a subject exercising at an extremely high workload (412 watts) became exhausted after three minutes of continuous exercise. When the work was intermittent for one minute with a rest for two minutes, the subject was able to exercise for 24 minutes before becoming exhausted. With work periods reduced to 10 seconds with 20 seconds rest, the subject could complete the work within 30 minutes with no feelings of strain.

These studies indicate that intermittent exercise appears to be as beneficial as continuous. Exercising at a high intensity intermittently enables one to complete a workload without becoming totally exhausted.

III. EFFICIENCY OF ANAEROBIC WORK

When the energy requirements of the body exceed the rate of aerobic oxidation, anaerobic glycolysis increases (Whipp, Seard, & Wasserman, 1970). If the work rate is high, the oxygen available for metabolism may not be adequate for the energy needed by the muscles. The body would then rely on anaerobic glycolysis. Whipp, Seard, and Wasserman (1970) found that in exercise lasting four minutes or longer, with $\dot{V}O_2$ reaching steady-state conditions, anaerobic work was as efficient as aerobic work. The researchers speculated that the oxygen debt occurring early in exercise is paid back, at least in part, when steady-state exercise conditions occur. With exercise less than four minutes, the efficiency of anaerobic work appeared low. Gladden and Welch (1978) reported that heavy work has a lower efficiency than light work. The authors argue that this does not necessarily indicate that the heavy work efficiency is low because the energy was supplied by anaerobic sources.

There seem to be opposite views whether the low efficiency of heavy work is due to anaerobic contribution. The notion persists that anaerobic work is less efficient than steady-state aerobic work.

IV. ENERGY EXPENDITURE IN RUNNING

The O_2 cost of running is a factor in calculating energy expenditure. Bransford and Howley (1977) investigated the oxygen cost of the speed of running in trained distance runners and untrained (but active) men and women. A series of treadmill tests were given in which oxygen uptake was measured. The tests were seven minutes in duration at treadmill speeds from 144 to 307 m/min which was 57-85% of their $\dot{V}O_2$ max. The trained male distance runners ran with the lowest O_2 cost (having the highest maximal oxygen uptake) while the untrained females required the greatest amount of oxygen (having the lowest maximal oxygen uptake).

Margaria, Cerretelli, Aghemo, and Sassi (1963) found that the net energy consumption per kilogram per kilometer (kcal/kg/km) was constant and independent of speed with steady-state exercise. For running at speeds greater than five mph, the net cost of running on a level surface was found to be approximately 1 kcal/kg/km (or 1.61 kcal/kg/mile). This value was based on a measured metabolic rate for lying at rest. One shortcoming of this study is that it used only two subjects. The middle distance runners ran on the treadmill at speeds of 9-22 km/hr for 10-15 minutes with inclines from -20 to +15%.

Howley and Glover (1974) tested eight men and eight women running one mile at speeds regarded subjectively by the subjects as being comfortable. The average running speed was 195 ± 25 m/min for men and 137 ± 4 m/min for women. Resting metabolic rate was not measured but taken from a source which assumes certain body fat measures. The net caloric expenditure was more for women (1.53 ± 0.09 kcal/kg/mile) than men (1.43 ± 0.08 kcal/kg/mile). The average for men and women together was 1.48 kcal/kg/mile. The gross caloric cost found for women was 1.73 ± 0.09 kcal/kg/mile and for men, 1.57 ± 0.09 kcal/kg/mile.

Mayhew (1977) found similar values for caloric cost of running independent of speed at 0.97 kcal/kg/km (1.56 kcal/kg/mile). Nine trained male distance runners participated in the study, running at speeds between 134 to 295 m/min, in 6.7 m/min increments.

Fellingham, Roundy, Fisher, and Bryce (1978) reviewed several studies which indicated that the oxygen debt increased as workloads increased. Based on these results the following procedures were developed by Fellingham et al. (1978) to investigate the caloric cost of running: a resting metabolic rate would be established for each subject in the sitting position; the subject would run at a predetermined speed with oxygen cost measured; after the run, the subject would sit until preexercise resting costs had been reached. The caloric costs of 1 mile were determined with running speeds of five, seven and nine mph for each subject. The mean caloric costs for each in kcal/kg/mile were 1.50 ± 0.04; 1.50 ± 0.03, and 1.64 ± 0.03, respectively. They found that the $\dot{V}O_2$ max had a significant influence on caloric costs during running; at higher speeds, the subjects with a lower $\dot{V}O_2$ max tended to burn more calories. Since running is not completely aerobic at more intense loads, these authors suggested that the anaerobic contribution is the main cause for the increased caloric cost at these loads.

In summary, these studies indicate that the caloric cost of continuous running for a given distance is independent of speed when steady-state conditions are met. This conclusion however, does not apply for intermittent running when steady-state conditions do not occur.

V. EFFECTS OF GENDER ON ENERGY EXPENDITURE

There is not a universal agreement concerning the effect gender has on the caloric cost of running. Studies reported by Falls and Humphreys (1976) and Hagan, Stratham, and Gettman (1980) reported that the caloric cost of running was the same for men and women when it was related to body weight. Body weight is a factor that influences energy expenditure (Consolazio & Johnson, 1971). Since men generally weigh more than women, one might expect differences between males and females for gross energy expenditure.

In a study by Howley and Glover (1974), women expended significantly more calories per kilogram ($p < 0.05$) than men. These authors emphasize that different conclusions can be drawn depending on how the data are expressed. When expressed per unit surface area the differences were no longer significant but when expressed per unit lean body mass the differences were even greater than originally.

The above studies indicate that there are different findings concerning caloric expenditure (kcal/kg) between males and females. Further research may be indicated in this area.

CHAPTER III

METHODS

I. SELECTION OF SUBJECTS

Ten volunteers--five males and five females--from the University of Tennessee physical education classes were used as subjects in this study. The experimental procedures were explained and an informed consent was signed by each subject prior to participation (see Appendix A). Following this introduction to the study, each subject performed a maximal oxygen uptake test. The subjects then ran a moderate and high intensity workout. The order in which the workouts were performed was made by random assignment. Subjects did not perform more than one test on any given day. Table 1 lists the physical characteristics of the subjects.

II. PROCEDURES AND TECHNIQUES OF MEASUREMENT

The procedures for each subject consisted of: an accommodation period; a maximal oxygen uptake test; moderate and high intensity workouts with the components of baseline, exercise, and recovery measurements.

Accommodation to Testing Procedures

The subjects became familiar with the treadmill protocols before the testing date. They were instructed not to eat, smoke, or drink anything (except water) three hours prior to testing. The subjects

Table 1. Physical Characteristics of Subjects

Ss	Age (years)	Weight (kg)	$\dot{V}O_2$ max (L/min)	$\dot{V}O_2$ max ml(kg•min)$^{-1}$	Max HR (bpm)	V_E (BTPS)
Females						
1	24	56.75	2.63	46.26	192	94.63
2	25	61.74	2.42	39.27	186	91.83
3	21	56.75	2.52	44.42	186	80.59
4	19	58.34	2.80	48.01	192	83.65
5	20	60.72	3.34	54.93	204	112.83
$\bar{X}$	21.8	58.86	2.74	46.58	192	92.71
Males						
1	21	61.06	3.20	52.43	192	107.42
2	21	68.10	3.57	52.37	192	97.83
3	23	78.32	4.37	55.79	204	123.97
4	22	87.85	4.28	48.71	198	148.79
5	30	64.01	4.06	63.38	198	154.30
$\bar{X}$	23.4	71.87	3.90	54.54	197	126.46

reported to the lab at a designated time dressed in light gym clothing and running shoes. The subjects were weighed prior to each test.

Maximal Oxygen Uptake Test

A maximal oxygen uptake test was administered to each subject in order to determine the speed at which the subsequent workouts would be performed. Each test utilized a Quinton treadmill which was calibrated prior to testing with a stopwatch.

The maximal test began with a speed of 100 m/min at 0% grade. The speed increased every two minutes until the subject was unable to continue. Subsequent speeds were: 134, 174, 215, 241, 268 m/min. After a subject reached 268 m/min, the speed was decreased to 241 m/min while the grade increased to 5%. The speed was then held constant while the grade was increased 2.5% every two minutes until exhaustion (see Table B-1, Appendix B). During each minute of exercise an expired gas sample was collected in a meterological balloon and used to calculate oxygen uptake. The highest calculated value was considered the subjects' maximal oxygen uptake.

Baseline and Recovery Measurements

To establish baseline measurements, i.e., $\dot{V}O_2$, R value, caloric cost, and heart rate, the subjects walked for five minutes at 100 m/min at 0% grade prior to each exercise workout. Generally, an exercise baseline is more easily reproduced than a baseline at rest (Astrand & Rodahl, 1970). One bag of expired gas was collected during the last two minutes of the baseline measurement period.

Recovery measurements were made using the same grade and speed as baseline measurements. For 12 minutes following the exercise, one expired gas sample was collected every two minutes.

Moderate Intensity Workout

The moderate intensity workouts were based on 60% of the max $\dot{V}O_2$ (see Table B-2, Appendix B). In programs aimed at cardiovascular fitness and weight control 50-85% $\dot{V}O_2$ max is generally recommended.

Following the baseline procedures the subjects ran continuously for a distance of two miles at 0% grade at their predetermined running speed, followed by the 12 minutes recovery. Expired gases were collected every two minutes of the test while heart rate was monitored continuously.

High Intensity Workout

The high intensity workouts also consisted of running two miles using intermittent instead of continuous running. This enabled the subjects to run at a rate equal to 90% of their max $\dot{V}O_2$. Baseline procedures preceded the workout. The subjects then alternately ran 30 seconds and rested 30 seconds (while straddling the belt of the treadmill) until the two miles were completed. One expired gas sample was collected for every three runs and one for every three rest periods. Heart rate was monitored throughout the workout. (See Table B-2, Appendix B.) Recovery procedures were followed after the subject completed the last run.

Ventilation and Gas Exchange

Oxygen uptake was measured by the open circuit method utilizing meterological balloons and a Collins Triple "J" valve. The O_2 and CO_2 concentrations in the expired gases were analyzed by an Applied Electrochemistry S-3A O_2 Analyzer and Beckman LB2 CO_2 analyzer. These were calibrated using gases previously standardized by the Scholander technique (Scholander, 1947).

Inspired minute ventilation was measured with a Parkinson-Cowan CD4 dry gas meter and recorded with a Narco Biosystems DMP-4A recorder. The dry gas meter was calibrated against a 120-liter Collins gasometer. Relative humidity, temperature, and barometric pressure were measured prior to each test to determine the inspired ventilation in terms of standard temperature and pressure, dry (STPD). Oxygen uptake was calculated using the Haldane transformation (Fox & Mathews, 1981).

Caloric Cost Calculations

For each test, the O_2 cost for the exercise portions (baseline, run, and recovery) were totaled. The O_2 cost was calculated by: $\dot{V}O_2$ (L/min) / bag collected x caloric equivalent for 1 liter O_2 x time in minutes for the bag collected. The caloric equivalent for 1 liter of O_2 was based on the R value for each bag (Lusk, 1928).

The following calculations were made using the results from each bag:

1. The caloric cost of each portion of the workout (baseline, run, recovery) was totaled. In addition, baseline caloric costs was

multiplied by 12 to equate with the 12 minutes of recovery;

2. The baseline cost was subtracted from recovery cost to give the caloric expenditure above that of baseline;

3. The latter result was added to the run values to give the total caloric cost per workout. Calculations were also made to determine the number of workouts of each intensity which would be the equivalent of one pound of body fat.

Heart Rate

Surface electrodes were placed on the right clavicular-sternal joint and the 5th intercostal space in the anterior axillary line for a 2-lead chest electrocardiogram placement. A Narco-Biosystems DMP-4A recorder was used to record the ECG from which the heart rate was measured.

Statistics

A two-way analysis of variance was used to test for significant caloric differences between the two intensities and gender (Ary, Jacobs, & Razavieh, 1972). Generalizations were made at the $p < .10$ level.

CHAPTER IV

RESULTS

I. CALORIC COST

The total caloric expenditures found in this study for continuous running at moderate intensity and intermittent running at high intensity speeds for two miles is presented in Table 2. The high intensity intermittent workout required a significantly greater number of calories than the moderate intensity continuous workout for both males and females (Table D-1, Appendix D). There was also a significant difference between the total caloric expenditure of the males and females (Table D-1, Appendix D). This result was expected due to body weight differences. When the caloric cost was expressed in kcal/kg per two miles the differences were no longer significant (Table D-2, Appendix D).

The number of two mile workouts for each subject, to be equivalent to the caloric content of one pound of body fat was calculated for both workouts (Table D-1, Appendix C). The results indicated that the moderate intensity level requires 17 workouts (or 34 miles) compared to 14 high intensity workouts (or 28 miles).

II. SPEED OF RUNNING

The individual speeds of running are shown in Table C-2, Appendix C. Each speed was determined from the maximal oxygen uptake test. The average speeds at which the women ran the

Table 2. Caloric Expenditures for the Moderate and High Intensity Two Mile Workouts

	Moderate		High		Difference
Subject	kcal/run	kcal/kg	kcal/run	kcal/kg	kcal/run
Females					
1	174.21	3.07	217.90	3.88	43.69
2	194.15	3.17	234.74	3.84	40.59
3	178.88	3.15	211.08	3.72	32.20
4	186.05	3.20	211.37	3.59	25.32
5	203.48	3.34	247.07	4.06	43.59
$\bar{X}$	187.35	3.19	224.43	3.82	37.08
Males					
1	222.58	3.63	279.46	4.62	56.88
2	235.13	3.45	299.39	4.37	64.26
3	218.63	2.80	261.56	3.39	42.93
4	261.42	2.97	309.26	3.49	42.84
5	221.90	3.39	273.76	4.23	51.86
$\bar{X}$	231.93	3.25	283.69	4.02	51.75
$\bar{X}$	209.64	3.22	254.06	3.92	44.42

moderate and high intensity workouts were 150 and 232 m/min, respectively. The men averaged 170 and 253 m/min for the moderate and high intensity workouts, respectively.

Table C-3, Appendix C shows the mean values of $\dot{V}O_2$ at which the subjects were running during each of the workouts. In the high intensity intermittent workout, the speed was set at 90% of max. The short runs and rest periods can account for the lower calculated $\dot{V}O_2$ for this intensity.

The mean heart rate response for the different speeds is shown in Table C-4, Appendix C. The short runs and rest periods contributed to the lower heart rate responses of the high intensity workout.

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this investigation was to study the effect of two different running methods on energy expenditure. Although anaerobic work is known to be less efficient than work of an aerobic nature, most weight loss programs recommend a slow continuous exercise routine. The intent of this research was to determine if another approach to weight reduction might be justified.

I. DISCUSSION

Caloric Cost

The conclusion of Margaria et al. (1963) that the net energy consumption per kilogram body weight per kilometer is constant and independent of speed with steady-state exercise is only relevant in the present study to the measurement of the moderate continuous workout. The caloric cost per kilogram in this study was different than those that were found in other studies possibly because of the difference in methods for resting oxygen uptake and recovery measurement. The present study calculated the caloric cost for two miles in which a walking baseline and recovery data were included. Studies which were reviewed calculated the caloric cost for one mile with a resting baseline. The resting baseline consisted of various body positions for measurement--lying, sitting, and standing. In one case, the resting values were taken from a source which assumed certain body fat measures. One study also measured recovery. These differences account for some of the variation between the studies which were reported.

For the purpose of comparison, the average kilocalories per kilogram per mile in this study for the females were 1.60 and 1.91 for the moderate and high intensities, respectively. For the males, the values were 1.63 and 2.01 for the moderate and high intensities, respectively. The moderate intensity values corresponded to findings by Margaria et al. (1963) and were in the upper range of data by Fellingham et al. (1978). For the net caloric cost, Howley and Glover (1974) and Mayhew (1977) found lower values than the present study but the gross caloric cost was comparable.

There is no standard to which the caloric cost of the high intensity intermittent workouts could be compared. As this was non-steady-state exercise, the conclusion of Margaria et al. (1963) is not appropriate. The efficiency studies are inconclusive as to the association of increased caloric cost with anaerobic energy sources. The result that the caloric cost of the high intermittent intensity was significantly greater than the moderate continuous intensity was conclusive. The caloric difference between the two intensity levels was 21%. This was between the predicted range of 14-22% which was taken from the efficiencies of the anaerobic and aerobic contribution to the energy cost of work (Asmussen, 1946; Whipp &Wasserman, 1969). This caloric difference between the intensities would be notable for weight reduction programs. Results of this study could influence a change in the present recommendations for exercise with the purpose of losing weight in the healthy overweight population.

Table C-1, Appendix C, shows that one would need to run three additional moderate intensity workouts (or six miles) to expend the caloric equivalent of one pound of body fat as compared with the high intensity workout. This difference may not be worth the unpleasant experience that some of the subjects reported. The subjects' major complaint was aimed at the equipment necessary to collect expired gases, in particular, the mouthpiece and noseclip. Most stated that the exercise would be tolerable without the equipment, though the continuous moderate intensity was preferred. The recommendation to run intermittently at the high intensity may initially be inappropriate. However, after a fitness level at the lower intensity has been achieved, the higher intensity may be encouraged for those having persistent body weight problems. Exercising at the higher intensities may suppress appetite more than at lower levels. Further study may be indicated in this area.

Although the gross caloric cost was significantly higher in the males, when the kcal/kg were calculated there were no significant differences between the females and males. This is in agreement with the data from several other studies (Falls and Humphreys, 1976; Hagan et al., 1980). Howley and Glover (1974) reported significant differences in caloric cost between the males and females but the differences in measurements, with baseline and recovery, may account for any discrepancies.

Speed of Running

The variation in actual $\dot{V}O_2$ for the moderate intensity workouts ranged from 58% to 74%. The estimated speed was set at 60% of max $\dot{V}O_2$. The difference in measured $\dot{V}O_2$ was to be expected because the speeds were interpolated from those run during the maximal oxygen uptake test. Since steady-state conditions are not achieved until three to five minutes into exercise, the two minute stages used for the maximal oxygen uptake test would result in lower values. This would cause the interpolated speeds to be overestimated. Due to the higher results measured $\dot{V}O_2$ values were greater than was expected.

Based on the measured oxygen uptakes during the high intensity exercise, it appears as if the subjects did not run at 90% of $\dot{V}O_2$ max. However, as can be seen in Table C-2, Appendix C, the subjects did run at speeds estimated to be 90% of max $\dot{V}O_2$ speed. During the first 30 seconds of exercise, however, oxygen cannot be consumed fast enough to meet the energy demands. Thus, while running at 90% of $\dot{V}O_2$ max speed, most of the energy would be supplied anaerobically and would appear that subjects were running at only 71% of max $\dot{V}O_2$. Most of the subjects stated that they would not be able to complete the high intensity workout continuously due to the speed. Exercising at the high intensity intermittently, rather than continuously, enabled them to complete the exercise workout without undue fatigue. The ability to complete the higher intensity workout, with rests, builds more support for the incorporation of these workouts in weight loss programs.

The heart rate during the high intensity workout was 82% of maximal heart rate which was similar to the moderate intensity heart rate responses. This can be accounted for by the short running period and recovery between exercise bouts.

II. CONCLUSIONS

With the limits of the study, it is concluded that high intensity running has higher caloric cost when expressed both in total calories and kcal/kg than moderate intensity running. Therefore, a person running at a high (non-steady-state) intensity would lose weight (keeping all other weight control variables constant) at a higher rate than running at a moderate intensity.

III. RECOMMENDATIONS FOR FURTHER STUDY

1. A training study, using the two different running regimens is recommended. This would provide data to confirm a greater rate of weight loss with high intensity intermittent work, provided all other variables, such as caloric intake and other physical activity, are controlled. This may provide the opportunity to investigate greater appetite suppressant with higher intensity exercise levels.

2. This present study could be repeated using overweight subjects to assess the feasibility of the above recommendation.

LIST OF REFERENCES

LIST OF REFERENCES

American College of Sports Medicine. (1978). The recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. Medicine and Science in Sports, 10, vii-xi.

American College of Sports Medicine. (1983). Proper and improper weight loss programs. Medicine and Science in Sports and Exercise, 15, ix-xiii.

Ary, D., Jacobs, L. C., & Razavieh, A. (1972). Introduction to research in education. New York: Holt, Rinehart and Winston.

Asmussen, E. (1946). Aerobic recovery after anaerobiosis in rest and work. Acta Physiologica Scandinavica, 11, 197-210.

Astrand, I., Astrand, P.-O., Christensen, E. H., and Hedman, R. (1960). Intermittent muscular work. Acta Physiologica Scandinavica, 48, 448.

Astrand, P. O., & Rodahl, K. (1977). Textbook of work physiology (2nd ed.). New York: McGraw-Hill.

Bransford, D. R., & Howley, E. T. (1977). Oxygen cost of running in trained and untrained men and women. Medicine and Science in Sports, 9, 41-44.

Chirico, A. M., & Stunkard, A. J. (1960). Physical activity and human obesity. New England Journal of Medicine, 263, 935.

Christensen, E. H., Hedman, R., and Saltin, B. (1960). Intermittent and continuous running. Acta Physiologica Scandinavica, 50, 269.

Consolazio, C. F., & Johnson, H. L. (1971). Measurement of energy cost in humans. Federation Proceedings, 30, 1444-1453.

Falls, H. B., & Humphrey, L. D. (1976). Energy cost of running and walking in young women. Medicine and Science in Sports, 8, 9-13.

Fellingham, G. W., Roundy, E. S., Fisher, A. G., & Bryce, G. R. (1978). Caloric cost of walking and running. Medicine and Science in Sports, 10, 132-136.

Fox, E. L., & Mathews, D. K. (1981). The physiological basis of physical education and athletics (3rd ed.). Philadelphia, PA: Saunders College.

Franklin, B. A., & Rubenfire, M. (1980). Losing weight through exercise. Journal of the American Medical Association, 244, 377-379.

Gaesser, G. A., & Brooks, G. A. (1975). Muscular efficiency during steady-rate exercise: Effects of speed and work rate. Journal of Applied Physiology, 38, 1132-1139.

Gladden, L. B., & Welch, H. G. (1978). Efficiency of anaerobic work. Journal of Applied Physiology, 44, 564-570.

Greene, J. A. (1939). Clinical study of the etiology of obesity. Annals of Internal Medicine, 12, 1797.

Hagan, R. D., Strathman, T., Strathman, L., & Gettman, L. R. (1980). Oxygen uptake and energy expenditure during horizontal treadmill running. Journal of Applied Physiology, 49, 571-757.

Howley, E. T., & Glover, M. (1974). The caloric costs of running and walking one mile for men and women. Medicine and Science in Sports, 6, 235-237.

Johnson, M. L., Burke, B. S., & Mayer, J. (1956). Relative importance of inactivity and overeating in the energy balance of obese high school girls. American Journal of Clinical Nutrition, 4, 37.

Lusk, G. (1928). Science of nutrition (4th ed.). Philadelphia: W. B. Saunders.

Margaria, R., Cerretelli, P., Aghemo, P., & Sassi, G. (1963). Energy cost of running. Journal of Applied Physiology, 18, 367-370.

Mayer, J., & Thomas, D. W. (1967). Regulation of food intake and obesity. Science, 159, 328.

Mayhew, J. L. (1977). Oxygen cost and energy expenditure of running in trained runners. British Journal of Sports Medicine, 11, 116-121.

Oscai, L. B. (1973). The role of exercise in weight control. Exercise and Sport Science Review, 1, 103-123.

Richardson, H. B. (1929). The respiratory quotient. Physiological Reviews, 9, 61-125.

Scholander, P. F. (1947). Analyzer for accurate estimation of respiratory gases in one-half cubic centimeter samples. Journal of Biological Chemistry, 167, 235-250.

Skinner, J. S., & McLellan, T. H. (1980). The transition from aerobic to anaerobic metabolism. Research Quarterly for Exercise and Sport, 51, 234-248.

Whipp, B. J., Seard, C., & Wasserman, K. (1970). Oxygen deficit-oxygen debt relationships and efficiency of anaerobic work. Journal of Applied Physiology, 28, 452-455.

Whipp, B. J., & Wasserman, K. (1969). Efficiency of muscular work. Journal of Applied Physiology, 26, 644-648.

Zuti, W. B., & Golding, L. A. (1976). Comparing diet and exercise as weight reduction tools. The Physician and Sportsmedicine, 4, 49-53.

APPENDICES

APPENDIX A

INFORMED CONSENT

Description of the Project

This study examines the differences in caloric expenditure in moderate and high intensity workouts for implications in weight loss programs. You will take three exercise tests in the study:

1. A maximal work capacity test (max $\dot{V}O_2$), running on the treadmill at a level grade with the speed being gradually increased. The test will continue to the point of voluntary exhaustion, which you alone will determine.
2. Running at a comfortable work-out speed (60% max $\dot{V}O_2$). This will be performed at a level grade for the duration of two miles.
3. Running at a higher intensity (90% max $\dot{V}O_2$). This also involves running for two miles in alternating intervals of 30 seconds on the treadmill and 30 seconds resting, by straddling the treadmill. You will not perform more than one test on any given day.

Possible Risks and Discomforts

You may perceive some degree of fatigue during all of the tests performed. Any of these may also cause you to experience muscle soreness which may persist for several days. The risks involved with exercise include the possibility of a heart attack, but this risk is very small for someone without known cardiovascular disease.

Subject Consent

I have read the above statement and understand my role in the experiment and the risks involved. The procedures have been explained to me and my questions have been answered to my satisfaction. In addition, I am aware that:

1. My scores will remain confidential;
2. I am entitled to answers for any further inquiries regarding the experiment;
3. I may withdraw from this study at any time without penalty or prejudice toward me;
4. In the event of physical injury because of my participation in this study, financial compensation is not available and medical treatment is not provided free of charge.

Date: Signature:

Date: Witness:

APPENDIX B

TESTING PROTOCOLS

Table B-1. Maximal Oxygen Uptake Protocol

Stage	min/Stage	mph	m/min	METS (est.)	Grade (%)	Bag Collection
1	2	3.75	100	3.9	0	one/min
2	2	5.0	134	8.6	0	one/min
3	2	6.5	174	11.0	0	one/min
4	2	8.0	215	13.3	0	one/min
5	2	9.0	241	14.8	0	one/min
6	2	10.0	268	16.3	0	one/min
7	2	9.0	241	17.9	5	one/min
8	2	9.0	241	19.4	7.5	one/min
9	2	9.0	241	21.0	10.0	one/min

Table B-2. Moderate and High Intensity Workout Protocol

Stage	min/stage	Speed	Grade	Bags
Baseline	5	100 m/min	0	1/last 2 min
Exercise	(min/stage and speed determined by the max test)		0	(M) 1/2 min (H) 1/3 runs 1/3 rests
Recovery	12	100 m/min	0	1/2 min

APPENDIX C

RESEARCH DATA

Table C-1. Number of Two Mile Workouts for Each Intensity Level Which Would Correspond to One Pound of Body Fat

Subject	Moderate Intensity	High Intensity (# workouts/# miles)	Difference (H-M)
Females			
1	20/40	16/32	4/8
2	18/36	15/30	3/6
3	20/40	17/34	3/6
4	19/38	17/34	2/4
5	17/34	14/28	3/6
$\bar{X}$	19/38	16/32	3/6
Males			
1	16/32	13/26	3/6
2	15/30	12/24	3/6
3	16/32	13/26	3/6
4	13/26	11/22	2/4
5	16/32	13/26	3/6
$\bar{X}$	15/30	12/24	3/6
$\bar{\bar{X}}$	17/34	14/28	3/6

Table C-2. Treadmill Speeds for the Moderate and High Intensity Workouts (m/min)

Subject	Moderate Intensity	High Intensity
Females		
1	148	243
2	134	215
3	133	243
4	161	220
5	174	241
$\bar{X}$	150	232
Males		
1	153	225
2	174	241
3	174	273
4	174	241
5	174	285
$\bar{X}$	170	253
$\bar{\bar{X}}$	160	243

Table C-3. The Interpolated and Calculated $\dot{V}O_2$ (in ml/kg-min) of the Moderate and High Intensity Workouts

Subject	Moderate			High		
	(Interpol./Calc./% max $\dot{V}O_2$)					
Females						
1	32.95	36.34	66	41.63	34.95	76
2	28.81	32.61	68	35.34	29.74	76
3	26.65	26.69	60	39.98	32.99	74
4	23.56	25.54	65	43.21	29.07	60
5	27.76	28.59	62	49.44	36.55	67
$\bar{X}$	27.95	29.95	64	41.92	32.66	71
Males						
1	31.46	34.90	67	47.19	39.86	76
2	31.42	38.54	74	47.13	39.12	75
3	33.47	32.26	59	50.21	37.60	67
4	29.23	33.22	68	43.84	33.49	69
5	38.03	36.62	58	57.04	44.35	70
$\bar{X}$	32.72	35.11	65	49.08	38.88	71
$\bar{\bar{X}}$	30.34	32.53	65	45.50	35.77	71

Table C-4. Heart Rate Responses to the Moderate and High Intensity Workouts

Subject	Max HR $(b{\cdot}min)^{-1}$	Mod. Int. (% of max HR)	High Int. (% of max HR)
Females			
1	192	72	83
2	186	81	85
3	186	74	80
4	192	*	87
5	204	83	77
$\bar{X}$	192	78	82
Males			
1	192	88	83
2	192	85	80
3	204	73	83
4	198	80	80
5	198	73	78
$\bar{X}$	197	80	81
$\bar{\bar{X}}$	195	79	82

*Not recorded due to bad connections of the ECG electrodes.

APPENDIX D

STATISTICAL ANALYSES

Table D-1. Two-Way ANOVA of the Total Caloric Cost Between Two Intensity Levels and Gender

Source	DF	Sum of Squares	F	Prob F
Intensity	1	9863.906	37.75	<.001
Error	8	2090.343		
Gender	1	13476.356	54.092	<.001
Int Gender	1	269.229		>.330
Error	8	1993.116	249.139	
Total	19	27692.950		

Table D-2. Two-Way ANOVA for Caloric Cost of Running Expressed in kcal/kg

Source	DF	Sum of Squares	F	Prob F
Intensity	1	2.464	16.537	<.003
Error	8	1.191		
Gender	1	.087	1.048	<.337
Int Gender	1	.025	.301	
Error	8	.661		
Total	19	4.428		

VITA

Sandra Jean Hewitt Clark was born in Jacksonville, Arkansas, on November 22, 1957. She graduated from Tehran American High School, Tehran, Iran, in 1975.

She entered the University of Central Arkansas in August of 1975. The following year she transferred to the University of Oklahoma. She received her Bachelor of Science degree in Nutrition-Dietetics from that institution in 1979. Following graduation, she completed a 10-month dietetic internship with Vanderbilt University Medical Center.

In August 1980 she accepted a position with the East Tennessee Regional Health Office as a community nutritionist. She passed the national dietetic registration exam to become a registered dietitian.

She began graduate studies part-time at the University of Tennessee, Knoxville, in 1982. There she completed the requirements for the Master of Science degree in Physical Education with an emphasis in the area of exercise physiology.

She is married to Bruce Alan Clark of Florence, Alabama.