8-1991

The relationship between extremes of resting metabolic rate and mechanical efficiency

Stephen D. Bailey

To the Graduate Council:

I am submitting herewith a thesis written by Stephen D. Bailey entitled "The relationship between extremes of resting metabolic rate and mechanical efficiency." I have examined the final electronic 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 Human Performance and Sport Studies.

Edward T. Howley, Major Professor

We have read this thesis and recommend its acceptance:

Wendy Bubb, Betsy Haugton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Stephen D. Bailey entitled "The Relationship Between Extremes of Resting Metabolic Rate and Mechanical Efficiency." 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 Human Performance and Sport Studies.

Edward T. Howley

Edward T. Howley, Major Professor

We have read this thesis
and recommend its acceptance:

Wendy J. Bubb

Betsy Haughton

Accepted for the Council:

Cwminkel

Vice Provost
and Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirement for a Master's degree at The University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature ______________________

Date 7-19-91

THE RELATIONSHIP BETWEEN EXTREMES OF RESTING METABOLIC RATE AND MECHANICAL EFFICIENCY

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Stephen D. Bailey

August, 1991

DEDICATION

To my family, for their support throughout my academic career and for their loving way of instilling in me the desire to reach for the capabilities that God has given me.

To my parents, for teaching me that my success can only be measured by my own heart and the Lord I strive to serve.

ACKNOWLEDGMENTS

In six years of study at The University of Tennessee, Knoxville, three professors markedly stand out as outstanding teachers and people. It is a great honor and privilege to have these three professors, Dr. Ed Howley, Dr. Wendy Bubb, and Dr. Betsy Haugton, as committee members.

I would like to thank Dr. Ed Howley, my major professor, for his guidance in both my academic and personal growth. His love and excitement for teaching, family, life, and laughter have and will continue to inspire me.

I would also like to express my appreciation to Dr. Wendy Bubb for inspiring me as well through her service to Christ. Her guidance through this project has been invaluable and has allowed me to complete a product that was otherwise impossible.

I would like to thank Dr. Betsy Haughton for also serving on my committee. Her questioning continually challenged me and I hope that her pursuit of excellence from me is evident in this work.

I wish to thank my dear friend Kathy Fisher for her continual love and support. Her smile has shined into my life and made the 90's a wonderful decade.

I would like to extend my gratitude to Dr. Buck Jones for doing what he does best - making a lasting impression on students' lives as he unselfishly serves the community.

I wish to thank the subjects who graciously participated in this project.

I also would like to thank the students, staff, and faculty of the Department of Human Performance and Sports Studies for being a second family. Bill, Ava, Don, Pam, Pete, Sammy Jill, Alun, Cammie, Jamieson, Martha, Yvonne, Dianne, Karen . . . everyone, you have a special place in my heart.

Finally, I wish to thank God for giving me this opportunity and for His many blessings.

ABSTRACT

Whether differences in energy metabolism, as manifested in resting metabolic rates, influence exercise metabolism raises important questions concerning energy balance in individuals. To address this issue, the relationship between extremes of resting metabolic rate and mechanical efficiency of cycle ergometer and treadmill exercise was investigated. Five subjects with high resting metabolic rates (1.20 ± 0.03 kcal/kg/hr) and six subjects with low resting metabolic rates (0.78 ± 0.01 kcal/kg/hr) participated in the study. Delta and gross efficiencies were calculated from the exercise response of the subjects during work on a cycle ergometer at work rates of 150, 300, and 450 kgm/min and on a treadmill at 80.4 mpm with grades of 3, 6, and 9%. Analysis of repeated measures revealed no significant differences for delta and gross efficiencies of the two groups on both the cycle ergometer and the treadmill. As an artifact of the calculation of gross efficiency, the extreme difference between the resting metabolic rates of the two groups resulted in a significant difference in the gross efficiency measurements at the initial intensity on the treadmill. It was concluded that mechanical efficiency is not influenced by extremes of resting metabolic rate and exercise remains an important component of the energy balance equation.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

Energy balance is a phrase that has emerged in the battle to maintain weight and fight the prevalent health problem of obesity. Obesity is the result of a prolonged positive energy balance; simply stated, weight is gained when energy intake exceeds energy expenditure. Acquiring knowledge about the mechanisms by which the body expends energy would shed light on the complications surrounding the treatment of obesity. These mechanisms involve energy metabolism at rest, the thermic effect of food, and exercise metabolism.

Decreases in resting metabolic rate have been noted when subjects are placed on very low calorie diets (Apfelbaum et al., 1971, Vansant et al, 1989). Furthermore, investigators have found that this metabolic adaptation may persist after caloric restriction has ceased and refeeding occurs (De Boer et al., 1986, Van Dale et al., 1990). If there is an alteration in cellular metabolism that results in differences in resting metabolic rates, exercise metabolism may also be affected.

Several investigations have revealed decreased energy expenditure during exercise in subjects who have been placed on very low calorie diets (Drenick and Dennin, 1973, Apfelbaum et al., 1977, De Boer et al., 1986). Controversy exists, however, between the findings of the studies that have looked directly at the relationship between caloric restriction, resting metabolic rate, and mechanical efficiency. Some studies (Ashworth, 1969, Edmundson, 1980) propose that subjects with lower resting metabolic rates, as a result of low energy intake, perform exercise with greater efficiency. Other investigators (Poole and Henson, 1988), however, conclude that this relationship does not exist. Although several studies have looked at the effects of changes in resting metabolic rates on mechanical efficiency, no literature exists that investigates the mechanical efficiencies of subjects predisposed with extremes in resting metabolic rates. If resting metabolic rates influence the mechanical efficiency of the individuals during exercise, difficulties in maintaining energy balance would be enhanced.

The purpose of this investigation was to determine the relationship between extremes of resting metabolic rate and mechanical efficiency of cycle ergometer and treadmill exercise.

CHAPTER II

REVIEW OF LITERATURE

Obesity is recognized as a major health problem with immense health implications. Kissebah et al. (1989) have summarized these health risks. Obesity is considered the most powerful risk factor for noninsulin-dependent diabetes mellitus. It is also highly associated with increased morbidity and mortality from cardiovascular disease. Several endocrine disorders and cancers have been strongly linked to obesity and overnutrition.

Obesity is the result of a prolonged imbalance of the simple energy equation involving energy intake and energy expenditure. If energy intake exceeds energy expenditure, weight is gained. However, if energy expenditure is greater than energy intake, weight is lost. Energy intake, of course, comes from dietary intake. Energy expenditure consists of three components: resting metabolic rate, diet-induced thermogenesis, and energy used for physical activity.

Resting metabolic rate (RMR) is the energy requirement needed to sustain the body's vital functions in the waking state (McArdle et al., 1991). RMR is noted specifically as being the oxygen consumption of an individual while he/she is resting quietly several hours after a meal or physical activity (Danforth, 1985). The energy metabolism at rest comprises approximately 60 to 75% of a person's total daily energy expenditure. Small variations in a person's resting metabolic rate extended over a long period of time would, therefore, have a large impact on total energy expenditure and thus significantly influence energy balance.

Very low calorie diets have been of interest in metabolic research due to their effects on RMR. Several studies have indicated an association between caloric restriction and a decrease in RMR (Bray, 1969, Apfelbaum et al., 1971, Drenick and Dennin, 1973, Apfelbaum et al., 1977, Barrows and Snook, 1987, Poole and Henson, 1988, Vansant et al., 1989). Apfelbaum et al. (1971) placed obese subjects on a 220 kcal diet for 15 days, resulting in an average decrease in RMR of 0.9% per day. Vansant et al. (1989) have noted that the decline in RMR is often associated with a decrease in fat-free mass (FFM), the most metabolically active tissue. However, even after correction for FFM, the resting metabolic rates of 15 obese subjects were still significantly reduced after 6 months on a very low calorie diet.

The metabolic adaptation that occurs with very low calorie dieting has also been shown to persist past the cessation of the restricted diet. Van Dale et al. (1990) measured the sleeping metabolic rate per kilogram fat-free mass of subjects who had completed an energy restricted diet treatment. Values were still depressed by 15.8% 32 or more months after treatment. Moreover, the adaptation to very low calorie diets, as shown by a decreased RMR, may persist upon refeeding (De Boer et al., 1986). After nearly 8 weeks on a calorie-reduced diet, the 24-hour energy expenditure of 14 overweight women had declined to 85% of initial values. Following 7 days of refeeding (100% of their pre-treatment diets), the 24-hour energy expenditure remained declined at a level lower than could be explained by the change in body weight and body fat. However, the continued depression of RMR after dietary treatments have ceased still remains controversial. Barrows and Snook (1987) found that when RMR was expressed relative to body surface area, RMR increased during the refeeding period after subjects were on a 420-kcal diet. They noted, however, that this increase in RMR occurred while mean body weight and, therefore, body surface area did not change. The fact that RMR changed independently of metabolic size is indicative of a metabolic adaptation during the caloric-restricted period.

As noted above, the changes that occur in RMR are usually greater than would be expected from changes in body mass. It has been proposed that 35% (Keys et al., 1950) to 65% (Grand et al., 1958) of the reduction in RMR can be attributed to decreased cellular metabolism. If this metabolic uncoupling, evident in the metabolic rate at rest, affects all daily activities such as exercise, the struggle for the obese to lose weight would be compounded when a very low calorie diet is undertaken.

Variations in exercise metabolism, one of the three components of energy expenditure, can be manifested in the efficiency of exercise. Mechanical or muscular efficiency is simply the ratio of work accomplished to the energy expended during steady-state exercise (Gaesser and Brooks, 1975). As noted by Poole and Henson (1988), "The efficiency of performing muscular work is determined by the combined efficiencies of the coupling of oxidation and phosphorylation and the coupling of phosphate-bond energy and muscular contraction."

There are several definitions of mechanical efficiency, with each expressing efficiency by accounting for different variables. Gross efficiency simply equals the external work accomplished divided by the energy expended to do the work. The calculation does not account, however, for any energy expenditure that may not be directly related to the performance of the measured external work (Stuart et al., 1981). The equation for the calculation of gross efficiency follows:

$$\text{gross efficiency} = \frac{\text{work accomplished}}{\text{energy expended}} \times 100\%$$

Net efficiency establishes a base-line correction factor by accounting for the energy expended at rest. Since resting metabolism does not contribute to the performance of the work, it is subtracted from the gross caloric output, resulting in the following equation:

$$\text{net efficiency} = \frac{\text{work accomplished}}{\text{energy expended above that at rest}} \times 100\%$$

The oxygen cost of moving the legs during cycle ergometer exercise is considered in the calculation of work efficiency. Whipp and Wasserman (1969) note that if this caloric expenditure is not accounted for, efficiency will be underestimated since the work done to move the legs is not included as part of the work accomplished. This adjustment results in the development of the formula for work efficiency:

$$\text{work efficiency} = \frac{\text{work accomplished}}{\text{energy expended above that in cycling without a load}} \times 100\%$$

Several authors recommend the use of delta efficiency to calculate mechanical efficiency (Gaesser and Brooks, 1975, Donovan and Brooks, 1977). Delta efficiency is the ratio of the caloric equivalent of the increment in work performed above the previous work rate to the increment in caloric output above that at the previous work rate. This equation produces the following formula:

$$\text{delta efficiency} = \frac{\text{delta work accomplished}}{\text{delta energy expended}} \times 100\%$$

The delta efficiency calculation accurately describes the relationship between caloric output and work rate by deriving the increase in oxygen consumption needed to maintain the increase in work rate (Gaesser and Brooks, 1975). In so doing, "delta efficiency is more sensitive to small changes than overall efficiency" (Gladden and Welch, 1978).

Few studies have looked directly at the relationship between caloric restriction, RMR and mechanical efficiency. However, the literature does reveal that decreased energy expenditure during exercise has been associated with very low calorie diets (Apfelbaum et al., 1971, Drenick and Dennin, 1973, Apfelbaum et al., 1977, De Boer et al., 1986). Drenick and Dennin (1973) suggest that improved work efficiency played a role in the 30% decrease in energy expenditure during walking in 10 ambulatory obese men after they fasted for two months. Apfelbaum and colleagues (1971) noted that weight variations in 41 obese subjects who consumed a restricted diet for 15 days could not account for 17.42% and 15.28% reductions in oxygen consumption during walking and climbing stairs, respectively. Similarly, Apfelbaum et al. (1977) found an approximate 20% decrease in energy expenditure during brake-free pedaling on a cycle ergometer in 11 moderately obese women placed on an energy-restricted diet for 2 weeks.

Developing countries set the stage for two interesting investigations of the effect of low calorie intakes on mechanical efficiency. Ashworth (1968) found that poorly nourished Jamaicans performed a standard step-test with a lower oxygen consumption than well-fed controls. The difference in efficiency was unrelated to differences in body weight. Edmundson (1980) studied Indonesians on low (avg. 1770 kcal) and high (avg. 2754 kcal) caloric intakes. The two groups, on average, did not differ significantly in height and mass. The resting metabolic rate of the low calorie intake subjects was almost half that of the high calorie intake controls (0.68 kcal/min vs. 1.32 kcal/min). Furthermore, the mechanical efficiency of the Indonesians on low caloric intakes was significantly higher when performing work on a cycle ergometer at 600 kpm/min. These findings are not consistent, however, with the investigation of Poole and Henson (1988). Thirteen moderately obese young women on 3 weeks of caloric restriction exhibited a 14% decrease in resting VO_2. Although there was a slight and consistent decrease in oxygen consumption at each work load on a cycle ergometer after caloric restriction, mechanical efficiency was not significantly altered.

Although there have been several studies looking at the effects of changes in RMRs, created by very low calorie dieting, on mechanical efficiency, there is no literature investigating the mechanical efficiencies of subjects predisposed with extremes in resting metabolic rates. Subjects with extremes in resting metabolic rates would experience the same difficulties in controlling the energy equation as obese individuals placed on very low calorie diets. If resting metabolic rates play a role in the mechanical efficiency of the individuals during exercise, these difficulties would be enhanced.

In summary, most investigators agree that there is a metabolic adaptation, as manifested in a declined RMR, in response to very low calorie diets. These findings raise the possibility of this metabolic adaptation affecting daily activities such as exercise. However, controversy still exists as limited research and conflicting findings make this link between energy intake and energy expenditure rather ambiguous. Valuable information about this link is needed in the treatment of obesity as energetic efficiency (low energy expenditure) may predict the onset or increase of obesity in both infants (Roberts et al., 1988) and adults (Ravussin et al., 1988). Therefore, investigations into the role of resting metabolic rates in mechanical efficiency are warranted and necessary.

CHAPTER III

METHODS

I. SELECTION OF SUBJECTS

One hundred college students volunteered as subjects and completed RMR measurements. Six females and five males were selected from this population based upon their extreme RMR values. (See Table 1 for physical characteristics of subjects.) Informed consent was obtained from each subject following an explanation of the experimental protocol, the risks involved, and the subject's rights (Appendix A). Each subject completed a health history and physical activity questionnaire (Appendix B). A four day food record was kept by each subject in order to assess caloric intake (Appendix C). Mechanical efficiency and maximal oxygen consumption tests were then performed on a cycle ergometer and a treadmill. The tests on the cycle ergometer and treadmill were separated by a minimum of 48 hours.

II. TECHNIQUES OF MEASUREMENT

Resting Metabolic Rate

The conventional open circuit spirometry technique was used to measure resting metabolic rate. Subjects reported to the laboratory having refrained from food, drink, or

TABLE 1

PHYSICAL CHARACTERISTICS OF THE SUBJECTS

Subject	Gender	Age (yr)	Body Weight (kg)	Resting Metabolic Rate (kcal/kg/hr)	VO_2 Max (Cycle) (ml/kg/min)	VO_2 Max (TM) (ml/kg/min)
			High RMR Group			
1	Female	23	56.92	1.20	45.69	47.32
2	Male	22	58.62	1.15	57.81	64.21
3	Male	23	54.48	1.17	40.53	43.12
4	Female	19	65.83	1.31	33.19	31.58
5	Male	22	91.71	1.14	36.57	44.38
$\overline{X}$		21.80	65.51	1.20	42.76	46.12
± SE		0.74	6.82	0.03	4.30	5.25
			Low RMR Group			
6	Female	22	64.75	0.79	28.51	30.39
7	Male	22	85.58	0.78	34.43	39.77
8	Female	39	61.68	0.76	33.50	36.85
9	Male	29	83.59	0.81	30.07	36.56
10	Female	24	53.00	0.75	26.24	27.36
11	Female	21	56.64	0.80	36.32	41.71
$\overline{X}$		26.17	67.54	0.78	31.51	35.44
± SE		2.82	5.64	0.01	1.58	2.25

exercise at least 4 hours prior to the test. The subject rested in a reclining chair for 20 minutes while breathing room air through a Daniels valve, with the nose occluded with a noseclip. Following this acclimation period, expired air was collected in a Douglas bag for 20 minutes. The oxygen and carbon dioxide concentrations of the expired air were determined by an Applied Electrochemistry S-3A O_2 analyzer and a Beckman LB2 CO_2 analyzer. The analyzers were regularly calibrated using known gases whose compositions were determined by the Scholander method. The volume of expired air was determined by noting the displacement of a 120-liter Collins gasometer from the air in the Douglas bag. Temperature and barometric pressure were recorded prior to each test and ventilation was calculated in terms of standard temperature and pressure, dry conditions. Oxygen uptake was converted to kcaloric expenditure and expressed per kg body weight per hour.

Cycle Ergometer Exercise

Mechanical Efficiency The submaximal tests for mechanical efficiency on the cycle ergometer followed a standard protocol. Subjects completed three or four stages of increasing intensity. The beginning work rate of each subject was 150 kpm/min. Resistance was increased in increments of 0.5 kp as subjects pedaled at a rate of 50 rpm. Visual and auditory cues were given by a metronome to insure proper cadence. Each stage was six minutes in duration with a two minute metabolic measure made between minutes four and six. Volumes of inspired air were measured by a Parkinson-Cowan CD-4 dry gas meter which was calibrated against a 120-liter gasometer. A 10-minute recovery period separated each stage. The subject's heart rate was monitored using a UNIQ CIC heart watch (Hempstead, NY). Mechanical efficiency testing was terminated when an intensity was reached which the subject could not maintain with a heart rate response at or below 85 percent of his/her age-predicted maximum heart rate. The ratio of the delta work accomplished to the delta energy expended between two stages, the delta mechanical efficiency, was used to express mechanical efficiency. Gross efficiency, the ratio of the work done to the energy expended at each stage, was also determined.

Maximal Oxygen Consumption At the conclusion of the final submaximal work stage, the subjects continued for a progressive maximal test. The work load was increased 0.5 kp every minute until the subject could not continue or maintain the cadence. Once a heart rate of 150 beats per minute was obtained, expired gas samples were collected every 60 seconds until the subject was unable to continue. The samples were used to calculate oxygen uptake according to standard procedures.

Treadmill Exercise

Mechanical Efficiency The protocol of submaximal tests for mechanical efficiency on the treadmill was very similar to the cycle ergometer protocol. Subjects completed stages walking at 80.4 meters per minute at increasing grades of 3, 6, 9, and 12 percent for 6 minutes each. Expired gases were measured the final 2 minutes of each stage by the open circuit spirometry technique. A 10-minute recovery period was taken between each stage. Measurements were also terminated when a work load was reached which resulted in a heart rate response above 85 percent of the subject's age-predicted maximum heart rate. Delta mechanical efficiency was calculated from the increase in energy expenditure needed to accomplish the increased work from one stage to the next. Gross mechanical efficiency was also calculated for each stage.

Maximal Oxygen Consumption At the conclusion of the mechanical efficiency testing, the subjects continued in a progressive maximal test. The grade was increased 3 percent every two minutes until the subject was unable to continue. Expired gases were collected every 60 seconds after a heart rate of 150 beats per minute was obtained. The samples were used to calculate oxygen uptake using standard procedures.

Statistical Analysis

The Student's t-test was used to test for significant differences between resting metabolic rates of the two groups. For delta efficiency, 2 x 2 factorial ANOVAs with repeated measures were used to test for significant group differences at 3 intensities for each separate mode of exercise. Likewise, for gross efficiency, 2 x 3 factorial ANOVAs with repeated measures were used to test for significant group differences at 3 intensities for each mode of exercise. Student's t-tests were also used to test for significant group differences at each intensity on the cycle ergometer and the treadmill for both delta and gross efficiencies.

CHAPTER IV

RESULTS

Three males and 2 females with high resting metabolic rates participated in the study. Mean values for weight, age, resting heart rate, and caloric intake for these subjects were 67.54 kg ± 13.82 kg, 26.17 yrs. ± 6.91 yrs., 66 bpm ± 8 bpm, and 3028.81 kcal. ± 828.09 kcal., respectively. Mean maximal aerobic power of the high RMR subjects as measured on the cycle ergometer and treadmill were 42.76 ml/kg/min ± 9.62 ml/kg/min and 46.12 ml/kg/min ± 11.75 ml/kg/min, respectively.

Four females and 2 males with low resting metabolic rates also participated in the study. The mean values for weight, age, resting heart rate, and caloric intake for the low RMR subjects were 65.51 kg ± 15.24 kg, 26.17 yrs. ± 6.91 yrs., 68 bpm ± 10 bpm, and 2177.92 kcal. ± 1200.11 kcal., respectively. Maximal oxygen consumption measured on a cycle ergometer and a treadmill resulted in mean values of 31.44 ml/kg/min ± 3.86 ml/kg/min and 35.44 ml/kg/min ± 5.52 ml/kg/min, respectively. The physical characteristics of individual subjects can be found in Table 1 in Chapter III.

No significant differences were observed between the mean weight, age, resting heart rate, and caloric intake values of the high and low RMR groups. The mean VO_2 max values for the two groups tested on the cycle ergometer were significantly different (p = .027), while a similar, yet insignificant, trend (p = .077) was observed for treadmill values.

I. RESTING METABOLIC RATE

Significant differences were observed in the resting metabolic rate of the groups (p = .0001). The individual measurements of RMR for each subject can be found in Appendix D, Tables 1-20, while the mean RMR for each subject is listed in Table 1 in Chapter III. Table 2 expresses the mean and standard error for each group. The summary of analysis of variance values may be found in Table F-6 in the Appendix.

TABLE 2

RESTING METABOLIC RATES OF HIGH AND LOW METABOLIC GROUPS

METABOLIC GROUP	N	MEAN	SE
HIGH	5	1.20	0.03
LOW	6	0.78	0.01

Means and standard errors for resting metabolic rates of both metabolic groups. Values are caloric expenditure in kcal/kg/hr.

II. DELTA EFFICIENCY

Table 3 and Table 4 list the mean data for delta efficiency measurements between the first and second intensities and the second and third intensities on the cycle ergometer and the treadmill, respectively. A third delta efficiency was not utilized due to several subjects' inability to complete the fourth and final intensity. Statistical analysis indicated no significant differences between the mean delta efficiencies of the high and low metabolic groups at each stage on the cycle ergometer and the treadmill ($p = .46$ and $p = .19$, respectively). The summaries of analysis of variance values may be found in Tables 7, 8, and 11-14 in Appendix F. Delta efficiency values for each participant can be seen in Appendix E, Tables 1-22.

TABLE 3

DELTA EFFICIENCIES OF HIGH AND LOW METABOLIC GROUPS ON CYCLE ERGOMETER

METABOLIC GROUP	$DELTA_{1,2}$ MEAN	$DELTA_{1,2}$ SE	$DELTA_{2,3}$ MEAN	$DELTA_{2,3}$ SE
HIGH	26.73	3.67	20.57	1.83
LOW	28.08	2.17	23.28	1.46

Means and standard errors of delta efficiencies of high and low metabolic groups on cycle ergometer. Subscripts denote intensities from which efficiency was calculated. Values are percentages.

TABLE 4

DELTA EFFICIENCIES OF HIGH AND LOW METABOLIC GROUPS ON TREADMILL

METABOLIC GROUP	$DELTA_{1,2}$ MEAN	SE	$DELTA_{2,3}$ MEAN	SE
HIGH	35.11	4.51	31.31	2.62
LOW	29.18	2.03	28.05	3.20

Means and standard errors of delta efficiencies of high and low metabolic groups on the treadmill. Subscripts denote intensities from which efficiency was calculated. Values are percentages.

III. GROSS EFFICIENCY

As can be seen from Tables F-9 and F-10 in the Appendix, no significant differences were found between the gross efficiencies of the groups at each intensity during both exercises. For reasons stated above, the fourth and final intensity was not statistically analyzed. The means and standard errors for each intensity on the cycle ergometer can be found in Table 5 and Figure 1. The means and standard errors for each intensity on the treadmill can be found in Table 6 and Figure 2. Individual calculations of gross efficiency for each subject are listed in Appendix E, Tables 1-22.

TABLE 5

GROSS EFFICIENCIES OF HIGH AND LOW METABOLIC GROUPS ON CYCLE ERGOMETER

	$GROSS_1$		$GROSS_2$		$GROSS_3$	
METABOLIC GROUP	MEAN	SE	MEAN	SE	MEAN	SE
HIGH	11.87	0.80	17.65	1.74	18.34	1.24
LOW	14.17	1.44	18.29	1.06	19.54	0.89

Means and standard errors of gross efficiencies of high and low metabolic groups on the cycle ergometer. Subscript denotes intensity from which efficiency was calculated. Values are percentages.

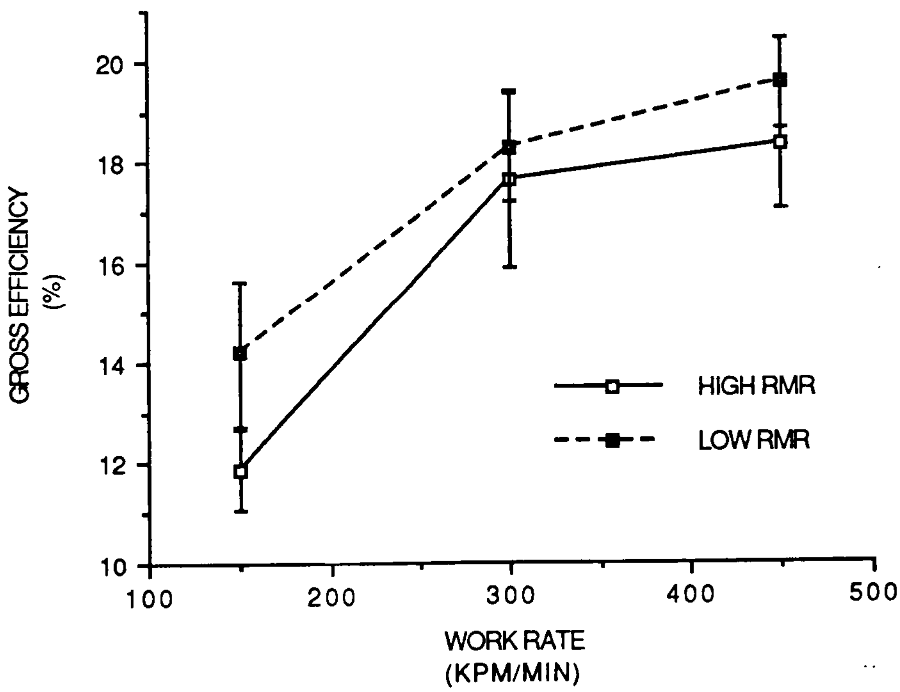

Figure 1. Gross efficiency of high and low resting metabolic rate groups on the cycle ergometer.

TABLE 6

GROSS EFFICIENCIES OF HIGH AND LOW METABOLIC GROUPS ON TREADMILL

METABOLIC GROUP	$GROSS_1$ MEAN	$GROSS_1$ SE	$GROSS_2$ MEAN	$GROSS_2$ SE	$GROSS_3$ MEAN	$GROSS_3$ SE
HIGH	7.22	0.30	11.89	0.63	14.92	0.68
LOW	8.51	0.38	13.16	0.54	15.97	0.74

Means and standard errors of gross efficiencies of high and low metabolic groups on the treadmill. Subscript denotes intensity from which efficiency was calculated. Values are percentages.

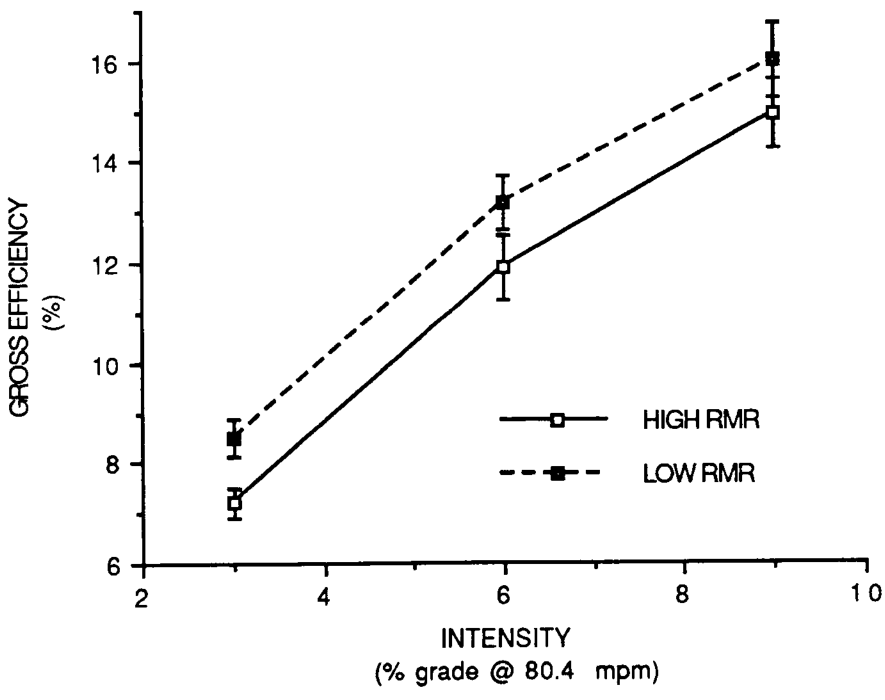

Figure 2. Gross efficiency of high and low resting metabolic rate groups on the treadmill.

CHAPTER V

DISCUSSION

The components involved in energy balance have received a vast amount of attention, especially as they are related to the treatment of obesity. The mechanisms by which the body expends energy provide an avenue of insight from which the energy balance equation can be better understood. This study addressed two of the components of energy expenditure by exploring the relationship between extremes of resting metabolic rate and mechanical efficiency. The study tested the hypothesis that mechanical efficiency is higher in subjects who have low resting metabolic rates compared to those who have high resting metabolic rates. This hypothesis was tested using mechanical efficiency measurements made on both a cycle ergometer and a treadmill.

The participants in the study comprised a homogenous group. There were no significant differences in age, weight, resting heart rate, caloric intake, and VO_2 max as measured on the treadmill between the high and low RMR groups. The VO_2 max of the high RMR group was significantly higher on the cycle ergometer compared to the low RMR group. The high RMR subjects were, however, more active and more familiar with the cycle ergometer.

I. RESTING METABOLIC RATE

In this study, the mean RMR of the subjects in the high RMR group was 35% higher compared to the low RMR group (1.197 kcal/kg/hr vs 0.782 kcal/kg/hr). This difference was so great that any variance found in individual measurements of RMR for each subject would be negated as two clearly different groups were defined. Subjects maintained normal eating and exercise habits throughout the study and had maintained their weight within 5 pounds for at least a month prior to the beginning of the study. Furthermore, the subjects abstained from food, drink and exercise for at least 4 hours prior to the testing. The RMR values correspond well with the findings of Edmundson (1980) who investigated the mechanical efficiencies of Indonesians with extremes in RMR values.

II. DELTA EFFICIENCY

If it were shown that a high metabolic efficiency, resulting in a low resting metabolic rate, transfers to efficiency of exercise insight would be provided into the complications surrounding energy balance. This study, however, did not provide evidence to support this hypothesis. The differences in delta efficiency between the low and high RMR groups while performing external work on a cycle ergometer and a treadmill were nonsignificant.

The ranges of delta efficiency values for the cycle ergometer (20.57%-28.08%) and the treadmill (28.05%-35.11%) are similar to those found in other investigations (Gaesser and Brooks, 1975, Donovan and Brooks, 1977, Gladden and Welch, 1978, Stuart et al., 1981). Gaesser and Brooks (1975) observed delta efficiencies at similar workloads ranging from 24.4% - 34.0% for exercise on a cycle ergometer. Donovan and Brooks (1977) reported delta efficiencies of treadmill exercise in close agreement with the values calculated in this study.

The pattern of decreasing delta efficiency with increasing work rate also concurs with the pattern seen in the studies mentioned above. Energy expenditure has been noted to increase exponentially with increasing work rate (Donovan and Brooks, 1977). Consequently, efficiency would decrease with an increasing work rate since the ratio of work accomplished to energy expended defines efficiency. The negative slope of delta efficiency, therefore, further validates this study's results.

III. GROSS EFFICIENCY

The hypothesis that extremes in resting metabolic rate would affect mechanical efficiency was also not supported by gross efficiency findings. Calculations of gross efficiency for exercise on the cycle ergometer and the treadmill were not significantly different between the low and the high RMR groups. The calculated values are in close agreement with gross efficiency values previously reported in the literature (Gaesser and Brooks, 1975, Stuart et al., 1981).

Student's t-tests at individual intensities (Appendix F, Tables 15 - 20) revealed that there was a significant difference in efficiency between the two groups when walking on a 3% grade at 80.4 mpm on the treadmill. This finding was not totally unexpected given the role of RMR in the calculation of gross efficiency. Resting metabolic rate is part of the total energy expenditure measured for gross efficiency and constitutes a large percentage of energy expenditure at a lighter work load. Therefore, the distinct difference between the RMR values of the two groups became apparent in the initial calculation of gross efficiency on the treadmill. As work rate increases, energy expenditure at rest becomes a smaller component of the total energy expenditure and, consequently, efficiency appears to increase. This pattern is evident in the gross efficiency measurements of both groups on the cycle ergometer and the treadmill.

For similar reasons, Poole and Henson (1988) found differences in energy expenditure during zero Watt cycling when subjects were placed on acute caloric restriction which resulted in a significant decrease in RMR. The present study is in further agreement with Poole's and Henson's investigation in that metabolic adaptations did not alter efficiencies at higher work loads.

The ability to draw comparisons between this study and those of Ashworth (1968) and Edmundson (1980) is limited by the lack of similarities in procedures. In contrast to the findings of the present study, these authors found significant differences in oxygen consumption and efficiency during different activities between groups who differed in their energy intakes. However, the subjects of the current study were stratified solely on the basis of extremes of RMR as all subjects had adequate energy intake.

In conclusion, this study indicates that extremes of resting metabolic rate do not influence mechanical efficiency. In application, individuals who experience decreased RMR values in response to very low calorie diets should not expect metabolic adaptations to transfer to exercise metabolism. Furthermore, physical activity remains an important component of weight maintenance that is free of any metabolic variables that would alter its value. These conclusions are accompanied by the acknowledgment of the need of further research in this area which controls for variables such as activity or training level and tests subjects in normal nutritional status.

BIBLIOGRAPHY

BIBLIOGRAPHY

Apfelbaum, M., Bostsarron, J., & Lacatis, D. 1971. Effect of caloric restriction and excessive caloric intake on energy expenditure. American Journal of Clinical Nutrition 24:1405-1409.

Apfelbaum, M., Brigant, L., & Joliff, M. 1977. Effects of severe diet restriction on the oxygen consumption of obese women during exercise. International Journal of Obesity 1:387-393.

Ashworth, A. 1968. An investigation of very low calorie intakes reported in Jamaica. British Journal of Nutrition 22:341-355.

Barrows, K. & Snook, J. T. 1987. Effect of a high-protein, very-low-calorie diet on resting metabolism, thyroid hormones, and energy expenditure of obese middle-aged women. American Journal of Clinical Nutrition 45:391-398.

Bray, A. G. 1969. Effect of caloric restriction on energy expenditure in obese patients. Lancet 2:397-398.

Danforth, E. 1985. Diet and obesity. American Journal of Clinical Nutrition 41:1132-1145.

De Boer, J. O., Es, A., Roovers, L. A., Raaij, J., & Hautvast, J. 1986. Adaptation of energy metabolism of overweight women to low-energy intake, studied with whole-body calorimeters. American Journal of Clinical Nutrition 44:585-595.

Donovan, C. M. & Brooks, G. A. 1977. Muscular efficiency during steady-rate exercise II. Effects of walking speed and work rate. Journal of Applied Physiology 43(3):431-439.

Drenick, E.J. & Dennin, H. F. 1973. Energy expenditure in fasting obese men. Journal of Laboratory and Clinical Medicine 81(3):421-430.

Edmundson, W. 1980. Adaptation to undernutrition: How much food does man need? Social Science and Medicine 14D:119-126.

Gaesser, G. A. & Brooks, G. A. 1975. Muscular efficiency during steady-rate exercise: effects of speed and work rate. Journal of Applied Physiology 38(6):1132-1139.

Gladden, L. B. and Welch, H. G. 1978. Efficiency of anaerobic work. Journal of Applied Physiology 44(4): 564-570.

Grande, F., Anderson, J. T., & Keys, A. 1958. Changes of basal metabolic rate in man in semistarvation and refeeding. Journal of Applied Physiology 12:230-238.

Keys, A., Grozek, J., Henschel, A., Mickelson, O., & Taylor, H. L. 1950. The Biology of Human Starvation: Vol. 1 & 2. Minneapolis, MN: University of Minnesota Press.

Kissebah, A. H., Freedman, D. S., & Peiris, A. N. 1989. Health risks of obesity. Medical Clinics of North America 73(1):111-135.

McArdle, W. D., Katch, F.I., & Katch, V. L. 1991. Human energy expenditure during rest and physical activity. in Exercise Physiology: Energy, Nutrition, and Human Performance. Philadelphia: Lea & Febiger.

Poole, D. C., & Henson, L. C. 1988. Effect of acute caloric restriction on work efficiency. American Journal of Clinical Nutrition 47:15-18.

Ravussin, E., Lillioja, S., Knowler, W. C., Christin, L., Freymond, D., Abbott, W., Boyce, V., Howard, B. V., Bogardus, C. 1988. Reduced rate of energy expenditure as a risk factor for body-weight gain. New England Journal of Medicine 318(8):467-472.

Roberts, S. B., Savage, J., Coward, W. A., Chew, B., & Lucas, A. 1988. Energy expenditure and intake in infants born to lean and overweight mothers. New England Journal of Medicine 318(8):461-466.

Stuart, M. K., Howley, E. T., Gladden, L.B., and Cox, R. H. 1981. Efficiency of trained subjects differing in maximal oxygen uptake and type of training. Journal of Applied Physiology 50(2):444-449.

Van Dale, D., Saris, W. H. M., & Hoor, F. T. 1990. Weight Maintenance and resting metabolic rate 18-40 months after a diet/exercise treatment. International Journal of Obesity 14:347-359.

Vansant, G., Van Gaal, L., Van Acker, K., & De Leeuw, I. 1989. Short and long term effects of a very low calorie diet on resting metabolic rate and body composition. International Journal of Obesity 13 (suppl. 2):87-89.

Whipp, B.J. and Wasserman, K. 1969. Efficiency of muscular work. Journal of Applied Physiology 26(5):644-648.

APPENDICES

APPENDIX A

CONSENT FORM

DESCRIPTION OF PROJECT

The purpose of this project is to study the effect of extremes of resting metabolic rate on mechanical efficiency.

Resting metabolic rate (RMR) will be measured while you are lying on a lounge chair for a period of about 50 minutes. You will have a respiratory valve in your mouth during this time, and a nose clip will be used to block nasal breathing. A single 20-minute collection of your exhaled air will be made during the latter part of this time period.

Mechanical efficiency will be measured on both the treadmill and the bicycle ergometer. You will breath through a respiratory valve while walking on a treadmill. You will have a strap across your chest which will measure your heart rate as you walk a set pace for 4 intensities (increased slope) of 10 minutes each with a rest period between each. Gasses will be collected the last two minutes of each workload.

In measuring mechanical efficiency on the bicycle ergometer, you will be asked to pedal at a set cadence while breathing through a respiratory valve and having your heart rate monitored. The exercise test will consist of pedaling at 4 intensities (increased resistance) of 10 minutes each with a rest period between each. Gasses will be collected the last two minutes of each workload.

On subsequent days, you will be asked to complete maximal oxygen uptake tests on both pieces of equipment. In performing the maximal oxygen uptake test on the treadmill, you will walk at a set pace while the intensity (slope) is increased every minute until a heart rate of 150 beats per minute is reached. At this point the intensity will be increased every 2 minutes until you can no longer keep the pace because you are fatigued and the test will end. You will then be asked to walk slowly and cool down.

You will be pedaling at a set cadence when performing the maximal oxygen uptake test on the bicycle ergometer. The intensity (resistance) will be increased every minute until a heart rate of 150 beats per minute is reached. At this point the resistance will be increased every 2 minutes until you are unable to maintain the set cadence due to fatigue. You will then be asked to cool down with no resistance on the bicycle ergometer.

Gas collections obtained every 60 seconds during the final minutes of the two tests described above will be used to calculate your maximal aerobic power.

You will possibly feel localized muscular soreness in your legs up to two days following the higher intensity cycle and treadmill tests. The risks involved with exercise include the chance of cardiac incident in which you may experience arrhythmias or possible cardiac failure. However, the risk is very small in subjects with no known cardiovascular disease.

You will receive a careful measure of your resting metabolic rate and your metabolic responses to physical activity. These values are helpful in planning weight control programs.

I have read the statement above and understand my role in the experiment, and the risks involved. I have had the procedures explained and demonstrated to me. In addition, I am aware that:

1. My name and the results will remain confidential;
2. I am entitled to have any further inquires answered regarding the procedures;
3. I may withdraw my consent and discontinue participation at any time without penalty or prejudice toward me including any affect on my grades;
4. In the event of physical injury because of my participation in this study, financial compensation is not available and medical treatment will not be provided free of charge.

Signature:________________________________
Date:_______________

Witness:__________________________________
Date:_______________

Stephen D. Bailey
Rm. 349, HPR Bldg (974-5111)

Wendy J. Bubb
Rm. 336, HPR Bldg (974-5111)

Edward T. Howley
Rm. 333, HPR Bldg (974-5111)

APPENDIX B

HEALTH HISTORY INFORMATION FORM

Name:__________________________ Date: / /
Age:_________ Phone:_________________

****

1. Please check (YES/NO) if you presently have or have ever been diagnosed with any of the following diseases or symptoms:

SYMPTOM	YES	NO
Coronary Heart Disease	____	____
High blood pressure	____	____
Heart murmur	____	____
Rheumatic fever	____	____
Irregular heart beat	____	____
Pains in your heart and chest	____	____
Any heart problems	____	____
Stroke	____	____
Lung disease	____	____
Epilepsy	____	____
Anemia	____	____
Diabetes	____	____
Bronchial asthma	____	____
Kidney disease	____	____
Liver disease	____	____
Hay fever	____	____
Orthopedic problems	____	____
Feel faint or have spells of severe dizziness	____	____

2. Do you have any medical condition for which you are now receiving treatment?_________ If yes, please explain.____
____.

3. Are you presently taking any medication?_______________
If yes, please list.___________________________________.

4. On which of the following days do you usually exercise?
___Mon. ___Tues. ___Wedn. ___Thur. ___Fri.
___Sat. ___Sun.

5. On the days you exercise, how many minutes do you exercise?
___<10 ___11-20 ___21-30 ___31-40 ___41-50
___51-60 ___>60

6. How would you classify the intensity of your exercise? **Circle a number.**

0	1	2	3	4	5	6	7	8	9	10
	Very light		Light		Moderate		Hard		Very hard	

7. What percentage of your **regular** exercise consists of the following:
   Aerobic (jogging, cycling, rowing, etc.) ______%
   Anaerobic (weight lifting, sprints, etc.) ______%
   Recreational (tennis, racquetball, etc.) ______%
   Other:_______________________________ ______%

8. Are you currently dieting?________ If yes, what type?
___Weight loss ___Weight gain ___Medically prescribed
___Vegetarian ___Other:_________________________________
____.

9. Has your weight been steady (±5 lbs) for the last 3 months?___________. If no, what has the variation been?_________________________________.

APPENDIX C

TIPS FOR COMPLETING THE FOUR DAY FOOD RECORD

Write down everything you eat or drink for four days, Friday through Monday, from the time you get up until you go to bed. This includes all meals, snacks, study breaks, nibbling, late-night refrigerator raids. . . everything that you eat or drink.

Helpful Tips:

-To make it easy to remember what you ate, record what you have eaten as soon as possible after eating.

-Specify how the food was prepared. How was it cooked? Was it fresh, frozen, or canned? Was the food fried, steamed, baked, boiled, or broiled?

-Specify if canned products were packed in water, its own juice, or was syrup added? Was the juice or syrup drained or served before it was eaten? Include the brand name of canned foods.

-If you added condiments or spices to your food, such as mustard, mayo, steak sauce, margarine, butter, etc., include these and portion sizes.

-If you had bread, was it white, whole wheat, french, or cracked wheat? Was your milk 1% milk fat, 2% milk fat, or whole milk?

-Break down recipes into specific foods or into its components. For example, a peanut butter and jelly sandwich must be broken into certain amounts of peanut butter, jelly, and bread. Do the same for salads and casseroles.

-Make a real effort to estimate what portion of food you ate or drank. Record the amount by:

Number or count
Standard measuring cups or spoons
Size or dimension of serving in inches
Weight in ounces

-Refer to the portion sizes of the food models when considering how much of a food you ate or drank.

-Do not adjust your eating habits in order to avoid dealing with the food record.

APPENDIX D

RAW DATA

TABLE D-1

RAW DATA OF SUBJECT 1: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.44	17.07	3.49	6.29	0.249	0.218	0.87

TABLE D-2

RAW DATA OF SUBJECT 1: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.41	17.25	3.34	5.86	0.221	0.194	0.88

TABLE D-3

RAW DATA OF SUBJECT 2: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.72	16.74	3.54	5.20	0.227	0.182	0.80

TABLE D-4

RAW DATA OF SUBJECT 2: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.73	16.62	3.65	5.37	0.241	0.195	0.81

TABLE D-5

RAW DATA OF SUBJECT 3: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.45	17.50	3.05	6.07	0.215	0.183	0.85

TABLE D-6

RAW DATA OF SUBJECT 3: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.37	17.55	3.08	6.57	0.228	0.200	0.88

TABLE D-7

RAW DATA OF SUBJECT 4: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.30	17.68	3.02	9.12	0.303	0.273	0.90

TABLE D-8

RAW DATA OF SUBJECT 4: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.37	16.25	4.38	7.57	0.361	0.329	0.91

TABLE D-9

RAW DATA OF SUBJECT 5: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.50	16.39	4.11	7.62	0.355	0.311	0.88

TABLE D-10

RAW DATA OF SUBJECT 5: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.35	17.73	2.92	8.77	0.288	0.253	0.88

TABLE D-11

RAW DATA OF SUBJECT 6: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	78.98	18.51	2.51	7.02	0.169	0.174	1.03

TABLE D-12

RAW DATA OF SUBJECT 7: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.42	17.47	3.11	6.97	0.248	0.215	0.87

TABLE D-13

RAW DATA OF SUBJECT 7: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.74	17.03	3.23	5.80	0.237	0.186	0.78

TABLE D-14

RAW DATA OF SUBJECT 8: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.44	17.56	3.00	4.65	0.162	0.138	0.85

TABLE D-15

RAW DATA OF SUBJECT 9: RMR-1

Time Minutes	$F_{E N_2}$	$F_{E O_2}$	$F_{E CO_2}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.23	16.98	3.79	5.85	0.234	0.220	0.94

TABLE D-16

RAW DATA OF SUBJECT 9: RMR-2

Time Minutes	$F_{E N_2}$	$F_{E O_2}$	$F_{E CO_2}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.48	16.52	4.00	5.07	0.229	0.201	0.88

TABLE D-17

RAW DATA OF SUBJECT 10: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.58	16.81	3.61	3.30	0.141	0.118	0.84

TABLE D-18

RAW DATA OF SUBJECT 10: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.38	16.96	3.66	3.35	0.136	0.122	0.89

TABLE D-19

RAW DATA OF SUBJECT 11: RMR-1

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	79.83	16.75	3.42	4.08	0.179	0.138	0.77

TABLE D-20

RAW DATA OF SUBJECT 11: RMR-2

Time Minutes	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
20	78.70	18.72	2.58	8.30	0.176	0.212	1.20

TABLE D-21

RAW DATA OF SUBJECT 1: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.81	16.29	3.90	12.04	0.578	0.462	0.80
300	79.62	16.24	4.14	17.82	0.857	0.727	0.85
450	79.49	16.20	4.31	23.23	1.120	0.989	0.88
600	79.31	16.21	4.48	33.05	1.578	1.466	0.93
Max	78.80	17.46	3.74	77.65	2.650	2.890	1.09

TABLE D-22

RAW DATA OF SUBJECT 1: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.60	16.30	4.10	18.05	0.856	0.729	0.85
6.0	79.58	16.27	4.15	21.46	1.023	0.878	0.86
9.0	79.54	16.14	4.32	25.00	1.223	1.066	0.87
12.0	79.47	16.24	4.29	31.40	1.500	1.330	0.89
Max	78.91	17.58	3.51	79.80	2.650	2.780	1.05

TABLE D-23

RAW DATA OF SUBJECT 2: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	80.05	15.89	4.06	10.67	0.559	0.424	0.76
300	80.00	15.44	4.56	13.24	0.751	0.592	0.79
450	79.71	15.35	4.94	19.36	1.105	0.943	0.85
600	79.73	15.24	5.03	22.97	1.337	1.138	0.85
Max	78.15	17.00	4.85	90.90	3.396	4.431	1.30

TABLE D-24

RAW DATA OF SUBJECT 2: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.44	16.18	4.38	18.29	0.883	0.791	0.90
6.0	79.51	15.46	5.03	20.10	1.118	0.999	0.89
9.0	79.51	15.39	5.10	22.76	1.281	1.147	0.90
12.0	79.24	15.18	5.58	27.57	1.617	1.546	0.96
Max	78.54	18.05	3.41	136.17	3.765	4.632	1.23

TABLE D-25

RAW DATA OF SUBJECT 3: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.40	17.65	2.95	15.81	0.531	0.459	0.87
300	79.20	17.10	3.70	23.51	0.909	0.861	0.95
450	79.05	17.15	3.80	34.32	1.297	1.294	1.00
Max	78.51	18.33	3.16	89.28	2.211	2.814	1.27

TABLE D-26

RAW DATA OF SUBJECT 3: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.62	16.73	3.65	18.98	0.820	0.682	0.83
6.0	79.49	16.80	3.71	22.29	0.942	0.816	0.87
9.0	79.50	16.51	3.99	26.40	1.192	1.040	0.87
12.0	79.32	16.81	3.87	34.34	1.435	1.314	0.92
Max	78.83	17.42	3.75	67.91	2.352	2.533	1.08

TABLE D-27

RAW DATA OF SUBJECT 4: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.38	17.01	3.61	18.34	0.732	0.654	0.89
300	79.24	17.08	3.68	27.61	1.075	1.005	0.94
450	78.97	17.47	3.56	42.96	1.480	1.518	1.03
Max	78.50	18.57	2.93	98.01	2.188	2.862	1.31

TABLE D-28

RAW DATA OF SUBJECT 4: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.38	16.96	3.66	29.84	1.206	1.079	0.89
6.0	79.08	17.43	3.49	43.10	1.512	1.490	0.99
9.0	78.96	17.67	3.37	54.81	1.777	1.833	1.03
Max	78.72	18.19	3.09	78.07	2.081	2.399	1.15

TABLE D-29

RAW DATA OF SUBJECT 5: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.66	15.77	4.57	13.48	0.712	0.607	0.85
300	79.55	15.81	4.64	17.72	0.925	0.912	0.88
450	79.31	16.03	4.66	24.76	1.227	1.143	0.93
600	79.09	16.17	4.74	32.19	1.536	1.515	0.99
Max	78.54	17.56	3.90	104.24	3.370	4.030	1.20

TABLE D-30

RAW DATA OF SUBJECT 5: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.42	15.90	4.68	30.43	1.554	1.408	0.91
6.0	79.36	15.90	4.74	35.94	1.831	1.686	0.92
9.0	79.19	15.96	4.85	42.92	2.146	2.065	0.96
12.0	79.20	15.94	4.86	52.50	2.637	2.531	0.96
Max	78.62	17.17	4.21	112.16	4.090	4.690	1.15

TABLE D-31

RAW DATA OF SUBJECT 6: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.55	16.59	3.86	8.82	0.392	0.336	0.86
300	79.51	16.03	4.46	13.37	0.668	0.589	0.88
450	79.16	16.39	4.45	20.27	0.925	0.895	0.97
600	78.89	16.70	4.41	29.77	1.250	1.307	1.05
Max	78.44	17.87	3.69	63.07	1.844	2.326	1.26

TABLE D-32

RAW DATA OF SUBJECT 6: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.31	16.36	4.33	17.97	0.831	0.770	0.93
6.0	79.12	16.25	4.63	23.34	1.096	1.073	0.98
9.0	78.95	16.75	4.30	33.42	1.390	1.429	1.03
Max	78.43	18.26	3.31	78.14	1.975	2.580	1.31

TABLE D-33

RAW DATA OF SUBJECT 7: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.49	16.70	3.81	18.40	0.796	0.691	0.87
300	79.48	16.62	3.90	22.30	0.982	0.858	0.87
450	79.39	16.61	4.00	28.62	1.257	1.131	0.90
600	79.07	16.67	4.26	36.15	1.542	1.529	0.99
Max	78.40	17.95	3.65	104.93	2.973	3.829	1.29

TABLE D-34

RAW DATA OF SUBJECT 7: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.86	16.26	3.88	26.35	1.275	1.003	0.79
6.0	79.70	16.20	4.10	32.69	1.590	1.319	0.83
9.0	79.44	16.33	4.23	41.12	1.925	1.718	0.89
12.0	79.47	16.47	4.06	51.36	2.337	2.058	0.88
Max	78.77	17.41	3.82	97.70	3.381	3.715	1.10

TABLE D-35

RAW DATA OF SUBJECT 8: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.48	17.18	3.34	11.54	0.444	0.380	0.86
300	79.42	17.02	3.56	17.90	0.715	0.629	0.88
450	79.20	16.99	3.81	27.04	1.075	1.020	0.95
600	78.94	17.26	3.80	39.25	1.432	1.482	1.03
Max	78.46	18.41	3.13	86.48	2.062	2.701	1.31

TABLE D-36

RAW DATA OF SUBJECT 8: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.51	16.46	4.03	18.61	0.850	0.740	0.87
6.0	79.31	16.67	4.02	25.64	1.107	1.020	0.92
9.0	79.31	16.50	4.19	31.35	1.406	1.300	0.92
12.0	79.18	16.48	4.34	38.99	1.746	1.677	0.96
Max	78.46	17.44	4.10	67.97	2.284	2.787	1.22

TABLE D-37

RAW DATA OF SUBJECT 9: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E N_2}$	$F_{E O_2}$	$F_{E CO_2}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.53	16.08	4.39	13.13	0.650	0.569	0.88
300	79.40	16.12	4.48	18.33	0.895	0.812	0.91
450	79.18	16.11	4.71	25.41	1.232	1.187	0.96
600	79.08	16.08	4.84	33.67	1.636	1.619	0.99
Max	78.47	17.27	4.26	71.73	2.535	3.056	1.21

TABLE D-38

RAW DATA OF SUBJECT 9: TREADMILL

% Grade @ 80.4 mpm	$F_{E N_2}$	$F_{E O_2}$	$F_{E CO_2}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.59	16.10	4.31	22.03	1.062	0.937	0.88
6.0	79.46	16.05	4.49	26.52	1.317	1.177	0.89
9.0	79.51	16.03	4.46	32.72	1.517	1.447	0.95
12.0	79.19	16.33	4.48	45.44	2.104	2.018	0.96
Max	78.60	17.25	4.15	84.76	3.037	3.512	1.16

TABLE D-39

RAW DATA OF SUBJECT 10: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.40	16.68	3.92	11.59	0.502	0.449	0.90
300	79.18	17.03	3.79	19.78	0.778	0.743	0.96
450	78.98	17.69	3.33	31.50	1.016	1.040	1.02
Max	78.80	17.81	3.39	45.43	1.393	1.531	1.10

TABLE D-40

RAW DATA OF SUBJECT 10: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.40	16.73	3.87	17.17	0.734	0.656	0.89
6.0	79.15	16.73	4.12	23.20	0.980	0.947	0.97
9.0	79.04	17.03	3.93	30.08	1.173	1.173	1.00
Max	78.83	17.59	3.58	44.09	1.452	1.569	1.08

TABLE D-41

RAW DATA OF SUBJECT 11: CYCLE ERGOMETER

Work Rate kpm/min	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
150	79.50	17.60	2.90	13.12	0.450	0.374	0.83
300	79.45	17.09	3.46	18.72	0.735	0.639	0.87
450	79.35	16.57	4.08	23.91	1.058	0.965	0.91
600	78.88	17.04	4.08	34.47	1.329	1.399	1.05
Max	78.89	16.86	4.25	51.01	2.060	2.157	1.05

TABLE D-42

RAW DATA OF SUBJECT 11: TREADMILL

% Grade @ 80.4 mpm	$F_{E_{N_2}}$	$F_{E_{O_2}}$	$F_{E_{CO_2}}$	$\dot{V}_E$ L/Min STPD	$\dot{V}_{O_2}$ L/Min	$\dot{V}_{CO_2}$ L/Min	R
3.0	79.54	15.84	4.62	17.79	0.923	0.811	0.88
6.0	79.25	16.04	4.71	22.48	1.109	1.049	0.95
9.0	79.15	16.26	4.59	30.04	1.410	1.368	0.97
12.0	79.09	16.16	4.75	36.12	1.727	1.704	0.99
Max	78.64	17.48	3.88	70.37	2.365	2.723	1.15

APPENDIX E

DELTA AND GROSS EFFICIENCY

TABLE E-1

DELTA AND GROSS EFFICIENCY FOR SUBJECT 1:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		12.67
	25.23	
300		16.87
	26.56	
450		19.20
	15.00	
600		17.95

TABLE E-2

DELTA AND GROSS EFFICIENCY FOR SUBJECT 1:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		7.70
	38.78	
6.0		12.85
	32.47	
9.0		16.09
	23.05	
12.0		17.40

TABLE E-3

DELTA AND GROSS EFFICIENCY FOR SUBJECT 2:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		13.23
	37.32	
300		19.53
	19.77	
450		19.61
	31.17	
600		21.62

TABLE E-4

DELTA AND GROSS EFFICIENCY FOR SUBJECT 2:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		7.61
	28.99	
6.0		12.05
	40.44	
9.0		15.73
	18.69	
12.0		16.38

TABLE E-5

DELTA AND GROSS EFFICIENCY FOR SUBJECT 3:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		13.54
	18.16	
300		23.27
	17.38	
450		21.45

TABLE E-6

DELTA AND GROSS EFFICIENCY FOR SUBJECT 3:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		7.75
	48.50	
6.0		13.37
	25.15	
9.0		15.84
	24.16	
12.0		17.34

TABLE E-7

DELTA AND GROSS EFFICIENCY FOR SUBJECT 4:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		9.77
	20.08	
300		13.14
	16.55	
450		14.11

TABLE E-8

DELTA AND GROSS EFFICIENCY FOR SUBJECT 4:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		6.28
	22.01	
6.0		9.77
	27.45	
9.0		12.44

TABLE E-9

DELTA AND GROSS EFFICIENCY FOR SUBJECT 5:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		10.14
	32.84	
300		15.46
	22.60	
450		17.31
	21.35	
600		18.17

TABLE E-10

DELTA AND GROSS EFFICIENCY FOR SUBJECT 5:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		6.75
	37.28	
6.0		11.42
	31.04	
9.0		14.47
	21.09	
12.0		15.70

TABLE E-11

DELTA AND GROSS EFFICIENCY FOR SUBJECT 6:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		18.37
	25.83	
300		21.47
	25.76	
450		22.73
	21.00	
600		22.27

TABLE E-12

DELTA AND GROSS EFFICIENCY FOR SUBJECT 6:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		8.89
	26.54	
6.0		13.32
	24.25	
9.0		15.68

TABLE E-13

DELTA AND GROSS EFFICIENCY FOR SUBJECT 7:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		9.04
	38.64	
300		14.65
	25.21	
450		17.02
	22.31	
600		18.10

TABLE E-14

DELTA AND GROSS EFFICIENCY FOR SUBJECT 7:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		7.86
	30.17	
6.0		12.47
	27.20	
9.0		15.22
	17.63	
12.0		16.76

TABLE E-15

DELTA AND GROSS EFFICIENCY FOR SUBJECT 8:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		16.23
	26.28	
300		20.07
	18.92	
450		19.67
	18.90	
600		19.45

TABLE E-16

DELTA AND GROSS EFFICIENCY FOR SUBJECT 8:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		9.81
	26.44	
6.0		14.88
	23.60	
9.0		17.57
	19.77	
12.0		18.68

TABLE E-17

DELTA AND GROSS EFFICIENCY FOR SUBJECT 9:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		11.04
	28.08	
300		15.90
	20.20	
450		17.12
	16.90	
600		17.06

TABLE E-18

DELTA AND GROSS EFFICIENCY FOR SUBJECT 9:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		9.01
	37.09	
6.0		14.49
	42.83	
9.0		18.60
	15.85	
12.0		17.82

TABLE E-19

DELTA AND GROSS EFFICIENCY FOR SUBJECT 10:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		14.23
	24.86	
300		18.08
	28.02	
450		20.54

TABLE E-20

DELTA AND GROSS EFFICIENCY FOR SUBJECT 10:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		8.31
	22.98	
6.0		12.20
	29.56	
9.0		15.17

TABLE E-21

DELTA AND GROSS EFFICIENCY FOR SUBJECT 11:
CYCLE ERGOMETER

INTENSITY(kpm/min)	DELTA	GROSS
150		16.13
	24.81	
300		19.55
	21.55	
450		20.18
	23.65	
600		20.95

TABLE E-22

DELTA AND GROSS EFFICIENCY FOR SUBJECT 11:
TREADMILL

INTENSITY (% grade @ 80.4 mpm)	DELTA	GROSS
3.0		7.20
	31.86	
6.0		11.58
	20.82	
9.0		13.59
	19.62	
12.0		14.72

APPENDIX F

STATISTICAL ANALYSES

TABLE F-1

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN WEIGHTS OF HIGH AND LOW RMR GROUPS

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	11.217	.054	.8222
Error	9	1884.853		
Corrected total	10	1896.070		

TABLE F-2

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN AGES OF HIGH AND LOW RMR GROUPS

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	52.003	1.875	.2041
Error	9	249.633		
Corrected total	10	301.636		

TABLE F-3

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN RESTING HEART RATES OF HIGH AND LOW RMR GROUPS

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	5.867	.073	.7927
Error	9	720.133		
Corrected total	10	726.000		

TABLE F-4

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN VO_2 MAX OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	344.945	6.985	.0268
Error	9	444.430		
Corrected total	10	789.375		

TABLE F-5

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN VO_2 MAX OF HIGH AND LOW RMR GROUPS: TREADMILL

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	311.196	3.977	.0773
Error	9	704.220		
Corrected total	10	1015.416		

TABLE F-6

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN RESTING METABOLIC RATES OF HIGH AND LOW RMR GROUPS

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	.468	193.544	.0001
Error	9	.022		
Corrected total	10	.490		

TABLE F-7

REPEATED MEASURES ANOVA OF DELTA EFFICIENCY FOR HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	22.469	.608	.4555
Error	9	332.560		
Corrected total	10	355.029		

TABLE F-8

REPEATED MEASURES ANOVA OF DELTA EFFICIENCY FOR HIGH AND LOW RMR GROUPS: TREADMILL

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	115.359	2.023	.1887
Error	9	513.211		
Corrected total	10	628.560		

TABLE F-9

REPEATED MEASURES ANOVA OF GROSS EFFICIENCY FOR HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	15.615	.697	.4254
Error	9	201.678		
Corrected total	10	217.293		

TABLE F-10

REPEATED MEASURES ANOVA OF GROSS EFFICIENCY FOR HIGH AND LOW RMR GROUPS: TREADMILL

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	11.900	2.522	.1467
Error	9	42.466		
Corrected total	10	54.366		

TABLE F-11

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN DELTA EFFICIENCIES OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER (150 & 300 kpm/min)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	5.029	.110	.7473
Error	9	410.029		
Corrected total	10	415.058		

TABLE F-12

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN DELTA EFFICIENCIES OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER (300 & 450 kpm/min)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	19.900	1.369	.2720
Error	9	130.790		
Corrected total	10	150.690		

TABLE F-13

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN DELTA EFFICIENCIES OF HIGH AND LOW RMR GROUPS: TREADMILL (3% & 6% grade @ 80.4 mpm)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	96.031	1.630	.2337
Error	9	530.273		
Corrected total	10	626.304		

TABLE F-14

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN DELTA EFFICIENCIES OF HIGH AND LOW RMR GROUPS: TREADMILL (6% & 9% grade @ 80.4 mpm)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	29.051	.587	.4623
Error	9	445.424		
Corrected total	10	474.475		

TABLE F-15

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER (150 kpm/min)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	14.488	1.748	.2188
Error	9	74.607		
Corrected total	10	89.095		

TABLE F-16

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER (300 kpm/min)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	1.095	.104	.7544
Error	9	94.721		
Corrected total	10	95.816		

TABLE F-17

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: CYCLE ERGOMETER (450 kpm/min)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	3.968	.652	.4404
Error	9	54.806		
Corrected total	10	58.774		

TABLE F-18

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: TREADMILL (3% grade @ 80.4 mpm)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	4.585	6.820	.0282
Error	9	6.050		
Corrected total	10	10.635		

TABLE F-19

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: TREADMILL (6% grade @ 80.4 mpm)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	4.372	2.379	.1574
Error	9	16.542		
Corrected total	10	20.914		

TABLE F-20

STUDENT'S T-TEST FOR DIFFERENCE BETWEEN MEAN GROSS EFFICIENCIES OF HIGH AND LOW RMR GROUPS: TREADMILL (9% grade @ 80.4 mpm)

SOURCE	DF	SUM OF SQUARES	F	PROB > F
Model	1	3.037	1.065	.3290
Error	9	25.662		
Corrected total	10	28.699		

VITA

Stephen D. Bailey was born in Houston, Texas on May 1, 1967. He moved to Knoxville, Tennessee shortly thereafter and began attending public schools. He was graduated from Farragut High School in May of 1985.

Stephen entered The University of Tennessee, Knoxville the following September of 1985. He received a Bachelor of Science degree in Education, majoring in Physical Education with an emphasis in exercise physiology in 1989.

Following graduation, he continued study at The University of Tennessee, Knoxville while employed in the Department of Human Performance and Sports Studies as a graduate research assistant and a graduate teaching associate. He subsequently completed the requirements for the Master of Science degree in Human Performance and Sports Studies, with a concentration in exercise physiology. Following graduation, Mr. Bailey will enter the University of Indianapolis to pursue a Master of Science degree in Physical Therapy.