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CALORIC COST OF PERFORMING THE
PERRIER PARCOURSE FITNESS CIRCUIT

by

Robert Hayes Sleamaker

A Thesis Submitted to the Faculty of the
DEPARTMENT OF PHYSICAL EDUCATION
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA

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23 May 1982
Date

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TABLE OF CONTENTS

	Page
LIST OF TABLES	vii
LIST OF ILLUSTRATIONS	viii
ABSTRACT	ix
 CHAPTER	
1. THE PROBLEM	1
Introduction	1
Statement of the Problem	3
Limitations of the Study	3
2. REVIEW OF THE LITERATURE	4
Studies Investigating the Energy Cost of Walking and Running	4
Energy Cost of Weight Training, Calisthenics, and Related Exercises	6
Factors Affecting Energy Expenditure	8
Effect of Body Weight on Energy Expenditure	9
Effect of Age and Sex on Energy Expenditure	10
Effect of Environmental Temperature on Energy Expenditure	11
Sports Application of the Beckman MMC	12
3. METHODS AND PROCEDURES	14
Introduction	14
Subjects	15
Procedures	15
Physiological Monitoring	20
Calculation of Energy Expenditure	23
Statistical Methodology	24
4. RESULTS	25
5. DISCUSSION	35
Heart Rate	37

TABLE OF CONTENTS -- Continued

	Page
6. SUMMARY	40
Conclusions	42
APPENDIX A: CONSENT FOR PARTICIPATION IN ENERGY COST STUDY	43
APPENDIX B: THE CALORIC EQUIVALENTS OF OXYGEN FOR NONPROTEIN RESPIRATORY QUOTIENTS	47
APPENDIX C: ENERGY EXPENDITURE FORMULAE	49
REFERENCES	51

LIST OF TABLES

Table	Page
1. Individual physical and performance characteristics . . .	16
2. Individual gross energy expenditure values	26
3. Individual net energy expenditure values	27
4. Energy cost in men performing the Parcourse	28
5. Oxygen consumption	30
6. Heart rate data	31

LIST OF ILLUSTRATIONS

Figure	Page
1. Illustration of a Perrier Parcourse Fitness Circuit . . .	19
2. Breathing apparatus	21
3. HR and $\dot{V}O_2$ data for subject #4 during simulation II . . .	33
4. HR and $\dot{V}O_2$ data for subject #13 during simulation II . . .	34

ABSTRACT

The metabolic cost of performing a Perrier Parcourse Fitness Circuit was determined in 18 college-age men. A laboratory simulation of the Parcourse was conducted using a small treadmill for the running phase and apparatus similar to the various apparatus at each of the specific exercise stations on the Parcourse. Subjects completed two simulations on separate days, performing at a pace which enabled them to maintain a training heart rate of 70-85% of maximum heart rate. Metabolic data for rest, exercise, and recovery were collected and analyzed with a Beckman Metabolic Measurement Cart. The average total gross energy expenditure was 394.9 kcals for simulation I and 382.1 kcals for simulation II. It was concluded that performance of the Parcourse would be an adequate exercise for expending energy in programs emphasizing weight control and would be appropriate for cardiorespiratory endurance conditioning.

CHAPTER 1

THE PROBLEM

Introduction

Physical fitness has become a primary concern for an increasingly greater portion of the United States' population. With the many sports and recreational activities available to most citizens, the three components of physical fitness can be realized by the participant, i.e., muscle strength and endurance, flexibility, and cardiovascular endurance (Åstrand and Rodahl, 1977; Fox and Mathews, 1981). For improving an individual's fitness, the mode of activity is a major factor (Wilmore, 1974), equal in importance to the factors of frequency, intensity, and duration of the exercise (Crews and Roberts, 1976; Jackson, Sharkey and Johnson, 1968; Pollock, Cureton and Greniger, 1969; Sharkey, 1970). The increasing popularity of physical fitness is due, in part, to the wide variety of activities available to the participant. Of foremost concern to the participant is the selection of an activity which will not only be enjoyable, but will also lead to improvement in the three components of fitness previously mentioned.

The Perrier Parcourse Fitness Circuit installed on the University of Arizona campus, like all Perrier Parcourse circuits, was designed to offer overall fitness with exercises designed to improve flexibility, muscular strength and endurance, and cardiovascular endurance (Calhoun,

1979). The Parcourse on the University of Arizona campus is comprised of a series of eighteen exercise stations spaced over a 1.9 mile path. Other Perrier Parcourses vary in length. The sequence of the stations provides for warm-up, stretching, muscular strengthening, cardiovascular conditioning, and cool-down. Instructions along the course direct the participant to walk or run between exercise stations. Parcourse was designed to challenge the abilities of every person by having that person exercise within his or her capacity through maintenance of a specific heart rate range (Calhoun, 1979).

For all physical activities, it is important to consider the energy cost in order to evaluate the potential benefits of the exercise. Caloric expenditure from exercise is a critical factor in weight control (Bray and Bethune, 1974; Wilmore et al., 1978). Also, awareness of the energy demand of activities can serve a vital role in exercise prescription for people with low functional capacities. Considerable research has identified the energy cost of numerous forms of exercise including: running (Falls and Humphrey, 1976; Fellingham et al., 1978; Howley and Glover, 1974); swimming (Karpovich and Millman, 1944); weight training (McCardle and Foglia, 1969; Wilmore et al., 1978); cycling Adams, 1967; Dill, Seed and Marzulli, 1954); isometric exercises (Clarke, 1960); walking (Bobbert, 1960; Booyens and Keatinge, 1957; Falls and Humphrey, 1976); and aerobic dance (Igbanugo and Gutin, 1978). To date, no known research has investigated the energy cost of performing the Perrier Parcourse Fitness Circuit.

Statement of the Problem

The purpose of this study was to determine the energy cost in college-age men of performing the Perrier Parcourse Fitness Circuit. It is hypothesized that this type of activity would result in relatively high levels of energy expenditure.

Limitations of the Study

1. The metabolic measures used to calculate energy cost were collected during laboratory simulations of the Parcourse. Unfamiliarity with laboratory procedures, such as wearing a headgear, mouthpiece, nose clip, and electrocardiographic electrodes, and the presence of laboratory technicians, may have caused the subjects some anxiety. This could have resulted in physiological values which did not precisely duplicate these same values while directly performing the Parcourse outside the laboratory.
2. The energy demands of exercising on the Parcourse in this study were based on the premise that each subject exercised at a training heart rate range between 70-85 percent of his maximum heart rate.

CHAPTER 2

REVIEW OF THE LITERATURE

The following is a review of the literature concerned with the energy expenditure of those activities related to exercise experienced while performing the Perrier Parcourse Fitness Circuit. Also, factors affecting the metabolic cost of physical activities will be discussed.

Studies Investigating the Energy Cost of Walking and Running

Margaria et al. (1963) determined the energy expenditure of two experienced runners performing at various speeds. Oxygen consumption was measured with the closed circuit method. The net cost of running one mile on the level was found to be $1.56 \text{ kcal/kg}\cdot\text{mile}^{-1}$, and was constant and independent of speed, as long as the speed did not incur any oxygen debt.

Booyens and Keatinge (1957) measured the oxygen consumption of 10 men and 10 women walking at 3.4 mph and at 4.0 mph. These speeds were considered to be steady state work loads. Expired gases were collected and analyzed with open circuit spirometry. The mean energy expenditure value for men walking was $4.93 \text{ kcal/kg}\cdot\text{hr}^{-1}$ ($1.45 \text{ kcal/kg}\cdot\text{mile}^{-1}$) at 3.4 mph and $5.86 \text{ kcal/kg}\cdot\text{hr}^{-1}$ ($1.47 \text{ kcal/kg}\cdot\text{mile}^{-1}$) at 4.0 mph. Mean energy expenditures for women walking were 4.49 kcal/

$\text{kg}\cdot\text{hr}^{-1}$ ($1.32 \text{ kcal}/\text{kg}\cdot\text{mile}^{-1}$) at 3.4 mph and $5.12 \text{ kcal}/\text{kg}\cdot\text{hr}^{-1}$ ($1.28 \text{ kcal}/\text{kg}\cdot\text{mile}^{-1}$) at 4.0 mph.

Howley and Glover (1973), in an investigation comparing the caloric costs of running and walking, report a net expenditure of $1.43 \pm 0.8 \text{ kcal}/\text{kg}\cdot\text{mile}^{-1}$ for men running on a treadmill at an average speed of 195 ± 25 meters/min. The net expenditure for men walking on the treadmill at a speed of 82 ± 3 meters/min was $0.76 \pm 0.07 \text{ kcal}/\text{kg}\cdot\text{mile}^{-1}$, nearly half of the energy cost of running. It was concluded that running a given distance required more calories than walking the same distance.

Fellingham et al. (1978) determined the energy cost of 24 college-age male subjects of walking and running at various speeds over a distance of one mile. Oxygen consumption was assessed using an open circuit system, with continuous gas collection every 30 seconds through a rest and exercise period and through a recovery period which lasted until resting metabolic levels were reached. Mean energy costs in $\text{kcal}/\text{kg}\cdot\text{mile}^{-1}$ for walking were 0.66 at 3 mph, 0.85 at 4 mph, and 1.24 at 5 mph. Mean energy costs for running were 1.50 at 5 mph, 1.50 at 7 mph, and 1.64 at 9 mph. In this study, only steady state levels of work were used for comparison with previous research results. Under the steady state assumption, it has been concluded that speed does not influence the caloric costs of running a given distance. The results of this study were in agreement with that conclusion, as the energy cost of the two steady state running levels, i.e., 5 mph and 7 mph, were equal. Therefore, at various running speeds slow enough to be assumed steady

state, the caloric cost of running a given distance would not be influenced by speed.

The energy cost of a three-hour race-walk exercise for men was established by Farley and Hamley (1978). Twenty national competition class race-walk men were observed in a controlled treadmill exercise. The treadmill was operated at a speed of 11.6 km/hr and the subjects were race-walked for three hours. Thirty minutes of pre-exercise and 30 minutes of post-exercise metabolic data were collected in addition to exercise metabolic data. Expired air samples were collected in Kofranyi-Michaelis spirometer, i.e., K-M meter, enabling the investigators to measure oxygen consumption. The mean net energy expenditure value for the exercise bout was determined to be 12.2 kcal/min. The work bout was considered submaximal.

Åstrand and Rodahl (1977) report energy expenditure values for men, mean weight 70-75 kg, running at various speeds. Running at 5.5 mph (9 km/hr) required 11.0 kcal/min., at 7 mph (11 km/hr) required 14.0 kcal/min., at 8 mph (13 km/hr) required 17.0 kcal/min., and at 10 mph (16 km/hr) required 20.0 kcal/min.

Energy Cost of Weight Training, Calisthenics, and Related Exercises

Wilmore et al. (1978) determined the energy cost of 20 men and 20 women, 17 to 36 years of age, performing circuit weight training. Subjects completed three circuits (10 stations/circuit), working for 30 seconds and resting for 15 seconds at each station. Metabolism was continuously assessed using the Beckman Metabolic Measurement Cart (MMC)

for 5 minutes at rest, 22.5 minutes of exercise, and for at least 12 minutes of recovery. Results indicated that the average gross energy expenditure for the exercise and recovery period was 9.0 kcal/min for men and 6.1 kcal/min for women. When expressed relative to lean body weight, women averaged 0.5% greater energy expenditure.

Durnin and Passmore (1967) report one measurement of the energy cost of weight training to be 8.2 kcal/min. However, the sex and weight of the individual measured was not specified.

McCardle and Foglia (1969) investigated the energy expenditure of six male subjects, mean age 19, performing the two-arm curl, the two-arm press, the bench press, and the squat weight training exercises. Each exercise was performed with a weight the subject could complete eight repetitions of the particular movement with. Metabolism was assessed by open-circuit spirometry using oxygen consumption as the measure of energy expenditure. Mean net oxygen consumption values for each exercise were as follows: 1033 ml O_2 for the two-arm curl; 1066 ml O_2 for the bench press; 1359 ml O_2 for the two-arm press; and 1596 ml O_2 for the squat. Each exercise had an average work time of 28 seconds. The authors approximated the energy cost of each activity to be 6.0 kcal/min.

Igbanugo and Butin (1978) determined the energy cost of aerobic dancing. Low, medium, and high-intensity dance routines were performed by two men and two women, ages 22-32. All subjects danced seven 2 to 3 minute routines at each intensity, alternated with six 15 to 90 second recovery intervals of continuous walking. Metabolic measures were

assessed using a Max Plank respirometer which measured ventilation and collected samples of expired air, which were analyzed for O_2 content. The women expended 3.9 kcal/min, 6.3 kcal/min, and 7.8 kcal/min for the low, medium and high-intensity routines, respectively, while the men expended 4.2 kcal/min, 6.9 kcal/min, and 9.4 kcal/min, respectively. The authors concluded that aerobic dance can be useful as a modality for cardiorespiratory training and rehabilitation, as well as for weight reduction and maintenance.

Amundsen et al. (1979) observed the energy cost of calisthenics designed for cardiac rehabilitation programs. Ten normal men, mean age 31.5 years, performed six calisthenic exercises. Each exercise was performed for five minutes to ensure steady state conditions. The exercises consisted of flexibility and abdominal strength movements. Metabolism was assessed with an open-circuit system. Expressed in METs (one Met = $3.5 \text{ ml } O_2/\text{kg}\cdot\text{min}^{-1}$), the MET energy cost of the exercise was found to be 1.2, 1.8, 2.1, 2.6, 3.6, and 4.1 for exercises one to six, respectively. The authors concluded that the calisthenics could be compared with low to moderate levels of other various exercises in terms of energy cost.

Factors Affecting Energy Expenditure

Fox and Mathews (1981) indicated that energy expenditure values were affected by the physical condition of the person, the person's degree of skill in executing a movement pattern, and the degree of effort employed while performing the activity. Fellingham et al. (1978) stated that an individual's level of fitness will have an effect on oxygen

consumption at steady state levels of work. The higher the fitness level, the less energy will be expended for a given activity.

Åstrand and Rodahl (1977) stated that the physiological and psychological effects of a given energy output were determined by the individual's maximal aerobic power, size of the engaged muscle mass, working position, whether work is intermittent at a high rate or continuous at a low rate, and environmental conditions.

Effect of Body Weight on Energy Expenditure

Mahadeva, Passmore and Woolf (1953) studied the energy expenditure of fifty persons varying in size and age, male and female, during the activities of bench stepping and walking. Energy expenditure was determined by indirect calorimetry. The Kofrayi-Michaelis calorimeter was utilized for expired gas collection. For bench stepping, results indicated that energy expenditure is directly proportional to body weight. The energy cost of bench stepping for all subjects was 4.82 kcal/min. For walking, the energy cost also was directly proportional to body weight. Mean expenditure for walking for all subjects was 4.45 kcal/min. The authors concluded that for any physical activity in which a large proportion of energy expenditure is used to move the body's weight, the metabolic cost is linearly proportional to the body weight.

Malhotra, Ramaswamy and Ray (1962) investigated the influence of body weight on energy expenditure. They tested 58 soldiers, ranging in weight from 48.9 to 87.0 kilograms, while performing various military

tasks. Results were conclusive that there existed a linear relationship between body weight and gross energy expenditure.

Van der Walt and Wyndham (1973) assessed the energy cost of six untrained males, ages 20-26, at various speeds walking (2, 3, 4, and 5 mph) and running (5, 6, 7, and 8 mph) on a level treadmill. Three measurements of oxygen consumption were made on each subject, at each of the work rates, on different days. Expired air was collected in Douglas bags over a two-minute period between the third and fifth minute of walking or running at each level. Oxygen consumption was determined through analysis of collected gas samples. Linear regression lines of oxygen consumption against body weight were calculated for each speed of running or walking. Correlations of 0.85-0.99 between body mass and oxygen consumption were highly significant at all speeds of walking and running. The investigators concluded that oxygen consumption was directly proportional to body mass during walking and running at a given speed.

Wilmore et al. (1978) investigated the energy cost of circuit weight training for 20 men and 20 women. The results of the study indicated that the energy expended was a direct function of the individual's body weight ($r = 0.84$ for men and $r = 0.67$ for women).

Effect of Age and Sex on Energy Expenditure

Adams (1967) made energy expenditure observations for bicycle riding in sixty adults, ages ranging from 20.0 to 53.2 years, 30 of each sex. Analysis of variance indicated that within the range studied, age

had no effect on the energy cost of bicycle riding. When gross energy expenditure values were expressed relative to body weight, there were no differences between males and females.

Mahadeva et al. (1953) found no influence of age or sex on the energy expenditures of men and women bench stepping and walking. The authors concluded that despite their importance in determining individual metabolic rates, age and sex do not assume sufficient importance to add to the precision in evaluating the energy expenditures of these activities.

More recently, Wilmore et al. (1978) observed that relative to total body weight, males averaged 15.6 percent greater energy expenditure than females for circuit weight training. However, in an attempt to identify any differences in body composition between males and females, energy expenditure data was expressed relative to lean body weight (LBW). On the basis of LBW, women averaged only a 0.5 percent higher energy expenditure, revealing no significant differences between the sexes.

Effect of Environmental Temperature on Energy Expenditure

Consolazio et al. (1963) compared metabolic rates of seven young men (ages 19-25), resting and performing moderate and heavy levels of bicycle ergometer work at three environmental temperatures of 70, 85, and 100°F. Testing was conducted in an environmental chamber in which the three temperatures were controlled and the relative humidity was maintained at 30%. Results showed that the men had significantly higher

metabolic rates at 100°F than at 85°F or 70°F. These increases averaged 11.4% for the heavy work level. No significant difference was observed in energy expenditure between the 70 and 85°F temperatures. The authors concluded that the significant threshold increase in metabolic rate must occur in temperatures above 85°F.

The effects of environmental temperature on energy cost in men was investigated by Hori et al. (1978). Metabolic measures were made on seven male subjects, ages 27-31, during bicycle ergometer work at a constant load of 600 kg-m/min in temperatures of 35, 30, and 23°C. An environmental chamber where temperature and humidity could be controlled was utilized for testing procedures. The authors found that the energy requirements for the activity was considerably greater at 35°C compared with 23°C. It was concluded that the energy expenditure for a fixed work load could increase significantly in a hot environment compared with a comfortable environment.

Sport Application of the Beckman MMC

Wilmore, Davis and Norton (1976) described a totally automated system for assessing metabolic and respiratory function during exercise. The system was called the Beckman Metabolic Measurement Cart (MMC), developed by Beckman Instruments, Inc. The MMC contained analyzers or sensors for measuring oxygen, carbon dioxide, expired air volume, expired air temperature, barometric pressure, and time. The instrument had a programmable calculator which was capable of computing and printing ventilation, oxygen consumption, carbon dioxide production, and the

respiratory exchange ratio. Compared simultaneously with two established systems for assessing respiratory and metabolic function, the MMC proved to be remarkably accurate. It was concluded that the MMC could be considered a valuable instrument in exercise metabolic testing.

The MMC was used to assess the energy expenditure of men and women while circuit weight training (Wilmore et al., 1978). The MMC was mobile and allowed continuous gas collection of the subject throughout the activity and recovery with a minimum of discomfort and considerable freedom of movement afforded the subject.

In a study comparing the maximum oxygen uptake values of tethered swimming and treadmill running, Creighton (1981) utilized the MMC for collecting metabolic data. Use of the MMC proved to be a valid procedure for metabolic assessments.

CHAPTER 3

METHODS AND PROCEDURES

Introduction

Subjects completed a graded treadmill test to volitional fatigue, and data was collected to determine their maximal oxygen uptake capacity (VO_2max) and maximal heart rate (HR max). In addition, the subjects underwent hydrostatic weighing to determine their body composition. Based on their achieved HR max, subjects were assigned a training heart rate range (THR) between 70 and 85 percent of their HR max. The assigned THR was expressed in beats/10 sec so that the subject only had to palpate his pulse for 10 seconds. The subject was asked to practice performing the Parcourse at a pace which would enable him to maintain a heart rate within his perscribed THR. The subject then performed the Parcourse at his THR pace, wearing a portable 24-hour electrocardiogram recorder for the duration of the course. This procedure allowed his actual heart rate to be recorded directly during the activity and to be subsequently reduced to 1-min averages by a microprocessor data reduction program. Also, the investigator followed the subject around the Parcourse to measure and record the time taken to run between exercise stations, the time spent at each exercise station, and the number of repetitions completed at each station. These time interval data were considered valid, provided that the recorded heart rate data indicated

that the subject performed the circuit maintaining his THR. The subject then completed two simulations of the Parcourse in the Exercise and Sports Sciences Laboratory at the University of Arizona. Heart rate and metabolic data were collected during resting, exercise, and recovery for each subject. The two simulations were performed on separate days.

Subjects

The subjects were 18 healthy college male volunteers between the ages of 18 and 26 years (mean age = 21.4 years). Individual physical and performance characteristics including age, weight (kg), percent relative body fat, lean body weight (LBW kg), fat weight (kg), resting heart rate (beats/min), maximal heart rate (HR max beats/min) and maximal oxygen uptake capacity ($\dot{V}O_2$ max ml/kg·min⁻¹) are summarized in Table 1. The study and procedures were explained to each subject and a written informed consent form was signed (see Appendix A).

Procedures

The first exercise test was a graded treadmill test to exhaustion, i.e., sign-symptom limited, volitional fatigue. Acquaintance with the treadmill and the procedures used in the test was made just prior to testing. A demonstration of the testing procedure was given, and the subject was allowed to practice. The test began with a 2-minute warm-up, walking at 3 mph and a 0 percent grade. This was followed by 2 minutes of jogging at 6 mph and 0 percent grade. The speed was increased to 8 mph for the next two minutes, with the grade remaining at 0 percent. The speed remained at 8 mph for the duration of the test, but the grade

Table 1. Individual physical and performance characteristics.

Subject	Age	Weight kg	% Fat	LBW kg	Fat Wt. kg	HR Rest beats/min	HR max beats/min	VO ₂ max ml/kg·min ⁻¹
1	26	100.2	28.9	71.1	29.0	74	201	40.5
2	21	71.5	18.5	58.2	13.2	75	202	51.1
3	21	70.5	10.1	63.4	7.1	66	188	64.6
4	24	91.2	10.8	81.2	9.9	60	185	57.8
5	21	92.6	15.1	78.6	14.0	78	184	47.3
6	20	66.4	10.4	59.4	6.9	58	205	49.0
7	18	66.5	12.1	58.4	8.0	83	198	52.8
8	22	78.5	10.8	70.0	8.5	52	187	56.6
9	20	70.0	14.0	60.1	9.8	54	202	58.3
10	18	53.0	10.4	47.4	5.5	80	204	59.8
11	19	92.3	15.3	78.1	14.1	76	208	42.9
12	26	59.2	7.0	55.0	4.1	74	184	44.9
13	24	69.7	8.7	63.6	6.1	58	192	63.3
14	24	83.1	11.6	73.3	9.7	64	202	49.8
15	20	71.2	12.4	62.3	8.8	70	202	55.3
16	23	73.0	9.0	66.4	6.5	62	192	53.7
17	20	83.2	8.3	76.3	6.9	65	194	52.3
18	18	80.0	18.6	65.1	14.9	86	208	52.4
<hr/>								
$\bar{x}$	21.3	76.2	12.9	66.0	10.2	68.6	196.5	52.9
S.D.	2.5	12.4	5.1	9.1	5.6	10.1	8.3	6.6

was then increased by 2 percent each minute thereafter until the subject reached the point of exhaustion. Each subject was verbally encouraged to achieve the highest work level possible. To determine the validity of the test, three criteria were used. The heart rate had to reach a plateau, the respiratory exchange ratio (R) surpassed unity, and the $\dot{V}O_2$ reached a peak and then dropped.

A training heart rate range (THR) was then established between 70 and 85 percent of the subject's maximum heart rate achieved during the treadmill test to exhaustion. The subject was instructed in palpating and counting the pulse for a 10-second period. He was given written and verbal instructions concerning the Parcourse route and procedures. He was told to practice running the Parcourse, perform the exercise at each station, and palpate his pulse at each of the Heart Check stations on the course. He was to run and complete the exercise at a pace which would enable him to maintain his heart rate within the THR. It was necessary for him to pay close attention to the correct pace and the number of repetitions at each exercise station in order to maintain the THR.

After practicing the Parcourse, the subject was ready for the next test. The subject reported to the laboratory to be fitted to wear an Oxford Instruments Medilog portable electrocardiogram recorder. A two-electrode placement was used, one placed at the manubrium and the other at the V_5 position. The recorder was fastened to the waist by a belt, and the electrodes were taped to the body to provide stability of measurement. The subject then performed the Parcourse at his prescribed THR pace. The investigator followed the subject around the course to

record the following: (1) the time the subject took to run between each station; (2) the time the subject spent at each station; (3) the number of repetitions performed at each station; (4) the total time taken for completion of the course. Included in the time spent at each station was the time it took for the subject to palpate and count his pulse for 10 seconds at Heart Check stations 1, 5, 9, 13, and 18 (see Figure 1). The palpated heart rate was recorded as well. Upon completion of the test, the cassette was played back on an Oxford Instruments high-speed playback unit interfaced with a Cromemco computer, which was programmed to count the number of heart beats per minute. The computer was connected to a printer, and a printout of the heart rates for each minute was obtained. If 75 percent of the individual minute heart rates were within the THR for the subject, then the test was considered acceptable. If this criterion was not met, the subject repeated the procedure on another day, attempting to maintain the THR pace. Of the 18 subjects, 13 were required to repeat the procedure a second time. When it was confirmed that the subject had run the Parcourse at the desired pace, then the time interval data was considered valid and could be used for the simulated Parcourse tests in the laboratory.

Next, the subjects performed two simulations of the Parcourse in the laboratory on separate days. Procedures and equipment were thoroughly explained prior to each test. For the intervals between each exercise station, the subject ran on a Quinton treadmill (Model 18-54), set to operate at a speed equal to the average running speed the subject achieved on the Parcourse. This treadmill was chosen because the belt

Figure 1. Illustration of a Perrier Parcourse Fitness Circuit.

platform was only 3 inches off the ground, enabling the subject to make a smooth transition on and off the treadmill at each exercise station. The time spent running on the treadmill between each exercise station matched the time measured and recorded on the Parcourse. Prior to completing each interval, the subject was alerted with the words "Five seconds, ready, stop," and the treadmill was turned off. The belt of the treadmill came to a gradual halt so that the subject was in no danger of falling.

Before each exercise station, the investigator reminded the subject of which station he was approaching and the number of repetitions he was required to perform. An illustrated map of the course (Figure 1), depicting each exercise station, was placed in full view in front of the subject. This enabled him to keep track of his position on the course. The exercises were performed on or within a few feet of the treadmill. Equipment was constructed to simulate that used on the Parcourse exercise stations, and was moved into place at the appropriate time during the simulation.

Physiological Monitoring

All metabolic measures were assessed by means of open-circuit spirometry. A Hans Rudolph respiratory valve (Series #2700) and low-resistance tubing were supported by a head piece worn by the subject (see Figure 2). During the simulated Parcourse exercise, the tubing was taped to a pole and held by a technician. The technician guided the subject to the areas for performing the exercises and facilitated the

Figure 2. Breathing apparatus.

movements of the subjects by supporting the tubing. A rubber mouthpiece was attached to the valve. The subject wore a nose clip in order to force all breathing to take place through the mouth. The tubing was connected to a Beckman Metabolic Measurement Cart (MMC), where the subject's expiratory gases and ventilation were analyzed. This instrument has been described and validated by Wilmore, Davis and Norton (1976). Before and after each test, the OM-11 oxygen analyzer and the LB-2 carbon dioxide analyzer housed in the MMC were calibrated with gases of known concentration. Calibration gas concentration was verified by the Scholander microtechnique. Gas volumes were measured with a biased flow turbine which was calibrated before testing each day using a Tissot gasometer at the flow rate estimated for that day's testing. Metabolic and respiratory measurements obtained included ventilation (VE), oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), and the respiratory exchange ratio (R). The data were analyzed and printed every 30 seconds. These procedures were used for the treadmill test to volitional fatigue, as well as for the two simulations of the Parcourse. However, for the simulations, resting metabolic data were collected for 5 minutes prior to exercise, and recovery metabolic data were collected for 10 minutes following exercise. The subject was seated in a chair during the resting and recovery periods. $\dot{V}O_2$ max was defined as the highest value obtained during the treadmill test to exhaustion.

During the simulated Parcourse tests and the treadmill test to fatigue, heart rate was monitored by means of a Hewlett-Packard 1514A ECG/Phono system, using three-lead electrode placement, i.e., manubrium,

V₅, and upper right abdomen. Heart rate was recorded at one-minute intervals throughout the tests. Resting and recovery heart rates were taken during the simulation. HR max was defined as the highest value recorded during the treadmill test to exhaustion.

Body composition analysis was conducted for each subject by the hydrostatic weighing technique (Behnke and Wilmore, 1974). Measures of lean body weight, fat body weight, and relative body fat (percent) were calculated for descriptive purposes, and to allow energy expenditure to be expressed relative to lean body weight.

Calculation of Energy Expenditure

Metabolic data was collected and printed for every 30 seconds by the Beckman MCC. From the printout obtained, oxygen consumption (l/min) for each 30-second interval was summed and then divided by 2 to obtain a gross oxygen consumption for the entire exercise and recovery period. A mean value for the respiratory exchange ratio (R) for exercise and recovery was calculated. Using the mean R value, the caloric equivalent value (kcal/l O₂) was determined (Appendix B). The calculation of gross energy expenditure then involved the multiplication of the gross oxygen consumption (l) by the caloric equivalent of R (kcal/l O₂). All formulae are displayed in Appendix C. Net energy expenditure was calculated by subtracting the resting energy expenditure from the gross energy expenditure. Energy expenditure was also expressed in kcal/min, kcal/kg·hr⁻¹, kcal/kg·(LBW)·hr⁻¹, as described in Appendix C.

Statistical Methodology

Statistical analysis included calculating the mean and standard deviation for the physical and performance characteristics of the subjects (Table 1). These included age (years), weight (kg), relative fat (%), lean body weight (kg), fat weight (kg), HR resting (bpm), HR max (bpm), and $\dot{V}O_2$ max ($\text{ml/kg}\cdot\text{min}^{-1}$).

Energy cost variables were statistically analyzed. Variables included gross and net energy expenditure expressed in total kcals, kcals/min, $\text{kcals/kg}\cdot\text{hr}^{-1}$, $\text{kcals/kg(LBW)}\cdot\text{hr}^{-1}$, and absolute and relative heart rate and $\dot{V}O_2$, i.e., HR (bpm), % HR max, $\dot{V}O_2$ ($\text{ml/kg}\cdot\text{min}^{-1}$), and % $\dot{V}O_2$ max. The means and standard deviations for these variables for simulations I and II were calculated for each subject. Group means and standard deviations were then calculated for each variable.

Correlations between simulations I and II were computed for each variable. The paired 't'-test for non-independent means were used to determine if significant differences existed between simulation I and II mean values for each variable.

Finally, the mean and standard deviations were computed for each subject's HR values recorded with a portable 24-hour electrocardiogram recorder (PECGR) during the subject's actual performance of the Par-course. A group mean and standard deviation for this variable was also calculated. Correlations of mean HR values between PECGR and simulation I, PECGR and simulation II, and simulations I and II were calculated. Paired 't'-tests were conducted for these variables as well.

CHAPTER 4

RESULTS

Individual gross energy expenditure values (total kcals and kcals/min) for the first and second Parcourse simulations are displayed in Table 2, along with group means and standard deviations. Simulation I-II correlations (Table 4) for gross energy expenditure in total kcals ($r = 0.96$) and in kcals/min ($r = 0.93$) indicated high reliability. Paired 't'-test results for simulation I-II for total kcals ($t = 2.56$) and for kcals/min ($t = 2.39$) were significant at the 0.05 level. However, closer inspection reveals that the mean energy expenditure for the second simulation was only 3.3 percent lower than for the first simulation for both methods of expressing energy expenditure.

Individual net energy expenditure values (total kcals and kcals/min) for the first and second Parcourse simulations are displayed in Table 3, along with group means and standard deviations. Simulation I-II correlations (Table 4) for net energy expenditure expressed in total kcals ($r = 0.95$) and in kcals/min ($r = 0.92$) indicated high reliability. Paired 't'-test results for simulation I-II for total kcals ($t = 2.02$) and for kcals/min ($t = 1.92$) were not significant at the 0.05 level.

For comparison with other energy cost studies, energy expenditure values were calculated in terms of $\text{kcal/kg}\cdot\text{hr}^{-1}$ and kcal/kg (LBW) .

Table 2. Individual gross energy expenditure values.

Subject	Simulation I (kcal/s)	Simulation II (kcal/s)	Simulation I (kcal/s/min)	Simulation II (kcal/s/min)
1	521.2	528.3	12.1	12.0
2	317.2	309.2	7.9	7.7
3	335.7	312.9	9.1	8.5
4	426.0	410.8	11.5	11.1
5	499.7	492.6	11.9	11.7
6	352.3	315.0	9.3	8.3
7	340.3	349.8	8.9	9.2
8	462.4	407.3	11.3	9.9
9	343.1	356.7	9.0	9.4
10	295.3	276.4	7.8	7.3
11	394.1	392.5	9.9	10.1
12	262.4	243.1	6.4	5.9
13	394.4	350.7	10.7	9.5
14	457.9	458.4	10.4	10.4
15	406.9	403.3	9.9	9.8
16	398.2	417.8	9.5	10.2
17	441.1	395.8	11.9	10.7
18	462.0	457.2	11.0	10.9
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$\bar{X}$	394.9	382.1	9.9	9.6
S.D.	71.9	65.3	1.6	1.6

Table 3. Individual net energy expenditure values.

Subject	Simulation I (kcal/s)	Simulation II (kcal/s)	Simulation I (kcal/s/min)	Simulation II (kcal/s/min)
1	429.4	441.3	10.0	10.1
2	288.5	274.9	7.2	6.9
3	283.6	285.6	7.7	7.7
4	340.8	327.4	9.2	8.9
5	407.8	424.2	9.7	10.1
6	288.4	259.8	7.6	6.8
7	282.8	289.6	7.4	7.6
8	399.7	341.9	9.8	8.3
9	285.5	303.1	7.5	7.9
10	238.1	223.1	6.3	5.9
11	355.4	353.1	8.9	9.1
12	223.8	204.4	5.5	5.0
13	323.2	286.1	8.7	7.7
14	395.2	379.1	9.0	8.6
15	337.7	332.8	8.2	8.1
16	341.2	358.9	8.1	8.8
17	360.8	332.1	9.8	9.0
18	398.0	386.9	9.5	9.2

$\bar{X}$	332.2	322.5	8.3	8.1
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S.D.	59.9	63.6	1.3	1.3
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Table 4. Energy cost in men performing the Parcourse.

Energy Expenditure	Simulation I		Simulation II		Correlation I vs II	't'-test I vs II
	Mean	S.D.	Mean	S.D.		
<u>Gross</u>						
Total kcals	394.9	71.9	382.1	75.3	0.96	2.56*
kcal/min	9.9	1.6	9.6	1.6	0.93	2.39*
kcal/kg·hr ⁻¹	7.9	0.8	7.6	0.7	0.81	2.43*
kcal/kg (LBW)·hr ⁻¹	9.0	0.9	8.7	0.9	0.83	2.45*
<u>Net</u>						
Total kcals	332.2	59.9	322.5	63.6	0.95	2.02
kcal/min	8.3	1.3	8.1	1.3	0.92	1.92
kcal/kg·hr ⁻¹	6.6	0.6	6.4	0.5	0.71	2.00
kcal/kg (LBW)·hr ⁻¹	7.6	0.7	7.4	0.7	0.78	2.06
<u>Heart Rate</u>						
bpm	160.5	12.8	157.5	13.2	0.87	1.92
% HR max	81.6	4.8	80.1	4.4	0.68	1.86
<u>Oxygen Consumption</u>						
ml/kg·min ⁻¹	32.9	3.3	32.1	3.0	0.81	1.83
% $\dot{V}O_2$ max	62.7	6.2	61.1	6.7	0.84	1.79

* Significant at the 0.05 level.

hr⁻¹. Means, standard deviations, correlations, and 't'-test results are presented in Table 4.

Each subject's mean oxygen uptake values (ml/kg·min⁻¹) for both simulations are displayed in Table 5, along with group means and standard deviations. Also presented in Table 5 is each subject's mean $\dot{V}O_2$ expressed as a percentage of his $\dot{V}O_2$ max. Group means and standard deviations are also listed. The correlation for mean $\dot{V}O_2$ between simulations I and II ($r = 0.81$) indicated high reliability. The paired 't'-test result ($t = 1.83$) for these values was not significant at the 0.05 level. The correlation for percent of $\dot{V}O_2$ max between simulations I and II ($r = 0.84$) also demonstrated high reliability. The paired 't'-test result ($t = 1.79$) for these values was not significant at the 0.05 level.

Individual heart rate data is presented in Table 6, along with group means and standard deviations. HR values are expressed in beats per minute (bpm), and as a percentage of HR max. Group means demonstrated that the THR of 70-85 percent of HR max was maintained for each test. Correlations for mean HR (bpm) between simulation I and II ($r = 0.87$), the Parcourse performance using a portable 24-hour electrocardiogram recorder (PECGR) and simulation I ($r = 0.82$), and PECGR and simulation II ($r = 0.88$) indicated high reliability. Correlations for % HR max were lower between simulations I and II ($r = 0.68$), PECGR and simulation I ($r = 0.57$), and PECGR and simulation II ($r = 0.71$). These lower correlations were due to a decrease in variability when expressed in relative terms. Paired 't'-test results for mean HR (bpm) for

Table 5. Oxygen consumption.

Subject	Simulation I	Simulation I	Simulation II	Simulation II
	Mean $\dot{V}O_{2-1}$ (ml/kg·min ⁻¹)	% $\dot{V}O_{2-1}$ max	Mean $\dot{V}O_{2-1}$ (ml/kg·min ⁻¹)	% $\dot{V}O_{2-1}$ max
1	30.3	74.8	29.9	73.8
2	28.0	54.8	27.7	54.1
3	32.7	50.7	30.6	47.4
4	33.1	57.3	31.8	55.0
5	32.5	68.6	31.9	67.6
6	35.3	72.0	32.8	66.9
7	35.0	66.4	35.9	68.2
8	36.7	64.9	31.5	55.6
9	33.4	57.3	34.5	59.2
10	36.0	60.2	35.1	58.8
11	27.4	63.8	28.3	65.9
12	26.9	59.9	24.7	55.1
13	38.4	60.7	35.4	55.9
14	31.2	62.6	31.3	62.8
15	34.9	63.2	34.4	62.3
16	31.7	59.0	34.7	64.6
17	35.9	68.7	32.6	62.3
18	33.7	64.4	34.8	66.4
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$\bar{X}$	32.9	62.7	32.1	61.1
S.D.	3.3	6.2	3.0	6.7

Table 6. Heart rate data.

Subject	PECGR Mean HR (bpm)	PECGR % HR max	Sim I Mean HR (bpm)	Sim I % HR max	Sim II Mean HR (bpm)	Sim II % HR max
1	167.7	83.4	163.8	81.5	164.3	81.7
2	159.6	79.0	160.8	79.6	157.0	77.7
3	143.7	76.4	146.9	78.2	148.9	79.2
4	151.2	81.7	132.3	71.5	142.1	76.8
5	147.2	80.0	154.8	84.1	151.0	82.1
6	169.8	82.8	171.8	83.8	166.3	81.1
7	178.9	90.3	174.0	87.9	175.8	88.8
8	149.6	79.9	155.9	83.4	134.8	72.1
9	158.7	78.6	163.4	80.9	161.8	80.1
10	154.8	75.9	160.0	78.5	157.9	77.4
11	159.4	75.6	179.1	86.1	172.4	82.9
12	148.9	80.9	151.5	82.3	143.9	78.2
13	138.9	72.4	145.1	75.6	138.8	72.3
14	166.8	82.6	168.3	83.3	173.2	85.8
15	162.0	80.2	165.9	82.2	161.2	79.8
16	149.8	78.0	152.3	79.3	154.9	80.7
17	152.1	78.4	158.0	81.4	150.4	77.5
18	178.7	85.9	184.7	88.8	180.8	86.9
$\bar{X}$	157.6	80.2	160.5	81.6	157.5	80.1
S.D.	11.4	4.1	12.8	4.2	13.2	4.4

simulation I-II, PECGR-simulation I, and PECGR-simulation II were 1.92, -1.62, and 0.08, respectively. None of these values were significant at the 0.05 level. Paired 't'-test results for percent HR max for simulation I-II, PECGR-simulation I, and PECGR-simulation II were 1.86, -1.55, and 0.15, respectively. Again, these values are not significant at the 0.05 level.

Figures 3 and 4 are graphs of the oxygen consumption data (30-second intervals) and HR data (1-minute intervals) for the second simulation by two subjects. Included in the graphs are symbols for each of the eight exercise stations (listed a-h), placed at the approximate time during the simulation when the subject performed the specific exercise. Both subjects' data followed similar trends. HR and $\dot{V}O_2$ steadily increased as the subject moved from the first warm-up stations to the more vigorous jumping jacks station (a) and the step-up station (b). These values decreased when the subject approached and performed the circle body station (c), a less strenuous activity. HR and $\dot{V}O_2$ increased to their highest levels during and between the body curl (d), the hop kick (e), and the push-ups (f) stations. Such exercises are strenuous and involve large muscle and upper body work. At the hand walk (g), and the balance beam (h) stations, the subject was cooling down and HR and $\dot{V}O_2$ decreased. Figure 1 offers a more descriptive illustration of the entire Perrier Parcourse Fitness Circuit.

Figure 3. HR and $\dot{V}O_2$ data for subject #4 during simulation II. -- See text for a definition of each symbol a-h.

Figure 4. HR and $\dot{V}O_2$ data for subject #13 during simulation II. -- See text for a definition of each symbol a-h.

CHAPTER 5

DISCUSSION

The physical and performance characteristics (Table 1) are in close agreement with previously reported data for college-age men (Wilmore et al., 1978). The subjects averaged a gross energy expenditure of 349.9 kcals for simulation I and 382.1 kcals for simulation II. The correlation between simulations I and II ($r = 0.96$) indicated high reliability, although the paired 't'-test indicated significant mean differences ($t = 2.56$) at the 0.05 level. However, the gross energy expenditure for simulation II was only 3.3% lower than for simulation I. The same results were noted for gross energy expenditure for simulations I and II when energy expenditure was expressed in other units. These differences in gross expenditure between simulations I and II are attributed to two factors. First, the person's skill in executing the movement patterns required during the simulation possibly increased on the second simulation. Fox and Mathews (1981) explain that an increased degree of skill in performing a movement pattern results in a greater efficiency, thereby reducing the energy cost. Inspection of Table 2 reveals that 13 of 18 subjects expended less energy during the second simulation. Secondly, the subjects became familiar with the testing procedures, i.e., use of headgear, nose clip, treadmill, apparatus, and technicians. Perhaps this allowed them to perform the second simulation

with more comfort and less psychological stress. Åstrand and Rodahl (1977) state that psychological factors can influence a given energy output of an activity.

Since no known research has investigated the energy cost of performing the Perrier Parcourse Fitness Circuit, it is difficult to compare the energy expenditure values determined in the present study with values from previous energy cost research. However, research has identified the energy cost of various activities involving physical movements related to those encountered on the Parcourse.

The mean gross energy expenditure expressed in kcals/min was 9.9 for simulation I and 9.6 for simulation II. The mean net energy expenditure expressed in kcals/min was 8.3 for simulation I and 8.1 for simulation II. The average time for performing the Parcourse was 29.6 minutes, with a range of 27.0-34.0 minutes and the average running speed of the subjects was 6.8 mph, with a range of 5.2-8.0 mph.

The energy cost of race-walking was determined by Farley and Hamley (1978), who found that 20 national competition race-walk men, averaging a speed of 7.2 mph, expended an average of 12.2 kcals/min. Åstrand and Rodahl (1977) report that the energy expenditure for men, mean weight 70-75 kg, running at a speed of 7 mph, is 14.0 kcals/min. In a study comparing the energy cost of running and walking, Howley and Glover (1974) found that men running at an average speed of 7.7 mph expended $11.1 \text{ kcals/kg}\cdot\text{hr}^{-1}$. This compares with the values of $7.9 \text{ kcals/kg}\cdot\text{hr}^{-1}$ for simulation I and $7.6 \text{ kcals/kg}\cdot\text{hr}^{-1}$ for simulation II (Table

4). Fellingham et al. (1978) found that college-age men running at 7.0 mph expended an average of $10.5 \text{ kcal/kg}\cdot\text{hr}^{-1}$.

Wilmore et al. (1978) determined the energy cost of college-age men performing circuit weight training. The average energy expenditure was 9.0 kcal/min . Expressed in $\text{kcal/kg}\cdot\text{hr}^{-1}$, the authors reported the energy cost to be 6.96. Durnin and Passmore (1967) report one measurement of energy cost for weight training to be 8.2 kcal/min , but the sex and weight of the individual were not specified. McCardle and Foglia (1969) determined the energy cost of six college-age men performing four different weight training exercises. The authors approximated the energy cost of each activity to be 6.0 kcal/min . The energy cost of low, medium, and high-intensity aerobic dance routines performed by two college-age men was determined to be 4.2 kcal/min , 6.9 kcal/min , and 9.4 kcal/min , respectively (Igbunugo and Gutin, 1978).

Since performance of the Parcourse involves both running and exercises similar to those described previously, it would seem appropriate that the energy cost of performing the Parcourse would be within the energy cost range of those activities. The amount of time spent running between stations and the amount of time spent at each station varied among subjects. On the average, the total time spent running was slightly greater than the total time spent at the exercise stations.

Heart Rate

The average HR elicited during the actual Parcourse performance (recorded with PECGR) and during simulations I and II (Table 6) by each

subject was within the THR of 70-85% of HR max. By maintaining the HR within the prescribed THR, standardization was established for the subsequent energy expenditure. HR monitoring for the Parcourse performance was accomplished with the use of an Oxford Instruments Medilog portable 24-hour electrocardiogram recorder (PECGR). The group means for HR (bpm) and % HR max for PECGR, simulation I, and simulation II were within 2% of each other. The correlations between PECGR and simulations I and II indicated a high degree of validity between the actual and the simulated performances. It is possible that the subjects became more familiar with the simulation procedure after the first simulation, allowing them to perform more comfortably and efficiently during the second simulation. This could explain the HR values for simulation II being close to those HR values recorded while performing the Parcourse. From inspection of the results, it would seem that HR monitoring using an Oxford Instruments Medilog portable 24-hour electrocardiogram recorder is a valid procedure.

It appears that performing the Parcourse while maintaining average HR values of 70-85% HR max would be appropriate for cardiorespiratory endurance training. Subjects exercised at 62.7% $\dot{V}O_2$ max for simulation I and at 61.1% $\dot{V}O_2$ max for simulation II, as displayed in Table 5. Research has found that a cardiorespiratory endurance conditioning benefit occurs when participants exercise at or about 60% of $\dot{V}O_2$ max (American College of Sports Medicine, 1980).

Performance of the Parcourse would be an adequate exercise for programs emphasizing weight control. Subjects expended 394.9 kcals for

simulation I and 382.1 kcals for simulation II. The average exercise time was 29.6 minutes. It has been recommended that those participants desiring to lose body weight should choose an activity which allows them to expend at least 300 kcals per exercise session (American College of Sports Medicine, 1980).

CHAPTER 6

SUMMARY

This investigation was designed to determine the energy cost in college-age men of performing the Perrier Parcourse Fitness Circuit. The Parcourse on the University of Arizona campus is comprised of a series of eighteen exercise stations spaced over a 1.9-mile path. The sequence of the stations provides for warm-up, stretching, muscular strengthening, cardiovascular conditioning, and cool-down. Instructions along the course direct the participant to walk or run between exercise stations.

The subjects were 18 healthy college male volunteers (mean age = 21.4 years). The subjects completed a graded treadmill test to volitional fatigue. VO_2 max and HR max values were determined. Body composition was determined for each subject by hydrostatic weighing. Each subject was prescribed a training heart rate range (THR) of 70-85 percent of his HR max. Each subject then performed the Parcourse at a pace which enabled him to maintain his HR within the prescribed THR. During this performance, his HR was recorded with a portable 24-hour electrocardiogram recorder which was fastened around his waist. The time taken to run between each station, the time spent at each station, and the number of repetitions performed at each station by the subject were recorded by the investigator. When it was determined that the subject had

completed the Parcourse at a pace which enabled him to maintain his THR, the data was considered valid. The subject then completed two simulations of the Parcourse in the Exercise and Sports Sciences Laboratory at the University of Arizona. A small treadmill was used for the running phases of the course, and the apparatus required for each exercise station was positioned for the subject at the appropriate time. HR and metabolic data were collected during rest, exercise, and recovery for each subject. All metabolic data was collected and analyzed with the Beckman MMC. The two simulations were performed on separate days.

The mean gross energy expenditure was 394.9 kcals (9.9 kcals/min) for simulation I and 382.1 kcals (9.6 kcals/min) for simulation II. The average length of time for completion of the Parcourse was 29.6 minutes. The mean net energy expenditure was 332.2 kcals (8.3 kcals/min) and 322.5 kcals (8.1 kcals/min) for simulations I and II, respectively.

Correlations for gross energy expenditure (kcals and kcals/min) between simulations I and II indicated high reliability ($r = 0.96$ and $r = 0.93$). Although paired 't'-tests for these variables were significant at the 0.05 level ($t = 2.56$ and $t = 2.39$), closer examination revealed that the energy cost of simulation II was only 3.3% lower than simulation I. This lower expenditure was attributed to an increased efficiency for performing the simulation.

Several factors should be considered in the application of the results of this study to other subjects. First, the subjects in this study were considered to be healthy and fit (mean $\dot{V}O_2$ max =

52.9 ml/kg·min⁻¹), and they were all college-age males (mean age 21.4 years). During testing, the environmental conditions were stable, with temperatures between 60 and 80°F. The effect of temperatures in this range is minimal (Consolazio et al., 1963; Hori et al., 1978). In this study energy expenditure was a direct function of body weight.

Conclusions

Within the scope of this study, the following conclusions may be made:

1. Simulation of the Parcourse in a laboratory setting for collection of metabolic data can be considered reliable.
2. HR monitoring using an Oxford Instruments Medilog portable 24-hour electrocardiogram recorder can be considered a valid method for measuring the HR of subjects as they perform exercises encountered on the Parcourse.
3. The efficiency for executing a movement pattern seems to be increasing with practice or familiarity of that movement. The mean energy expenditure for the second simulation was slightly lower than for the first simulation.
4. With respect to energy expenditure, performance of the Perrier Parcourse Fitness Circuit appears to be an excellent activity for purposes of weight control, and would be appropriate for cardiorespiratory endurance conditioning.

APPENDIX A

CONSENT FOR PARTICIPATION IN ENERGY COST STUDY

CONSENT FOR PARTICIPATION
IN
ENERGY COST STUDY
UNIVERSITY OF ARIZONA - TUCSON

I have been invited to participate in the above named research project. I understand the following:

Purpose: The purpose of the study is to provide information that will help define or characterize the physiological response of the human body to exercise on the Perrier Parcourse Fitness Circuit located on the campus of the University of Arizona.

Exercise: All subjects will participate in a series of physical fitness activities pertaining to the Parcourse. Exercise sessions and testing will be conducted during the month of November, 1981. Subjects will receive a detailed set of instructions describing the correct performance of the Parcourse. Also, verbal instructions will be given by the investigator. Each subject will undergo four exercise testing procedures, which include: (1) Performing the Parcourse at a pace which he feels would produce a training effect. During this time, the investigator will make the measurements of: (a) time taken to run between each exercise station; (b) number of repetitions at each station; (c) the total time for completion of the Parcourse; (2) Performing a simulated Parcourse in the Exercise and Sport Sciences Laboratory, 228 McKale Center, on two separate occasions. The simulated Parcourse requires that the subject run on a Quinton treadmill for the running phases of the circuit, and perform the station exercises with equipment constructed to simulate those of the Parcourse; (3) Completion of a treadmill exercise test to volitional fatigue to determine his maximal oxygen uptake capacity and maximal heart rate. Ten of the subjects will be chosen at random to complete two treadmill tests, on separate days, in order to determine the reliability of the data; (4) Performance of the Perrier Parcourse Fitness Circuit one additional time at a pace he feels would produce a training effect, while wearing the Medilog portable heart rate recorder. Estimated TOTAL testing time is 4 hours.

Respiratory Calorimetry: Subjects will be connected to the Beckman Metabolic Measurement Cart via a tube supported by a head brace during each of the simulated Parcourse sessions in the laboratory, and during the treadmill tests to volitional fatigue. The headgear will be worn for a total time of approximately 2 hours, including 20 minutes pre-exercise resting measurement, 30 minutes for each simulated Parcourse session, and 20 minutes for each treadmill test to volitional fatigue. The nose will be closed to breathing by means of a nose clip while the headgear is in place to force all breathing to take place through the mouth.

Miscellaneous:

1. Subjects should be familiar with the Perrier Parcourse Fitness Circuit exercises and procedures.
2. Subjects may not take any prescribed or over-the-counter drug or any other drugs on their exercise days before exercise sessions. No drugs may be taken on the days preceding the exercise sessions if such drugs have effects that last long enough to affect performance during exercise sessions.
3. Body composition and analysis will be measured by hydrostatic weighing.
4. It is estimated that subjects will spend a total of 4 hours on activities related to the study.
5. No medical coverage will be provided by the investigator except first aid for minor injuries.
6. The investigator will at any time answer any inquiries concerning procedures to be used.
7. Subjects are free to withdraw from the study at any time and for any reason without question from the investigator.
8. The subjects will be anonymous in any publication(s) of the results of this study.

Physical Examinations: Physical exams will not be given to the subjects. It is understood that subjects are physically fit to participate in the exercise sessions as they have been engaged in a regular exercise program prior to the study. If at any time a participant or the investigator believe that the health of a subject may be impaired, the subject may ask or be asked to drop from the study.

Risks: Potential risks are considered to be minimal. The subject may experience minor inconvenience and discomfort from wearing the headgear during testing in the laboratory. Also, there may be some muscular soreness resulting from the exercise sessions.

Benefits: Subjects will gain special understanding of the scientific method as applied to Exercise Physiology research. Subjects will also receive instruction in the correct performance of physical conditioning exercises, but these subjects are not expected to improve in physical performance during the study. Also, subjects will receive valuable fitness testing and interpretation of the results.

Compensation for Injuries: I understand that in the event of physical injury resulting from the research procedures, financial compensation for wages or time lost is not available, and the costs of medical care and hospitalization is not available and must be borne by the subject. I understand that Robert Hayes Sleamaker (626-1418 or 327-1647) will provide more information upon my request.

I have read the above, and the nature, demands, risks, and benefits of the study have been explained to me. I understand that I may ask questions and that I am free to withdraw from the project at any time without incurring ill will. I also understand that this consent form will be filed in an area designated by the Human Subjects Committee with access restricted to the principal investigator or authorized representatives of the particular department. A copy of this consent form is available to me upon request. I also understand that my data will be kept in strict confidence with only the principal investigators having access to my file.

Date

Signature

Date

Signature

APPENDIX B

THE CALORIC EQUIVALENTS OF OXYGEN FOR NONPROTEIN RESPIRATORY QUOTIENTS

The caloric equivalents of oxygen for nonprotein respiratory quotients.*

Nonprotein Respiratory Quotient	Oxygen	Carbon Dioxide
0.70	4.686	6.694
0.72	4.702	6.531
0.74	4.727	6.388
0.76	4.752	6.253
0.78	4.776	6.123
0.80	4.801	6.001
0.82	4.825	5.884
0.84	4.850	5.774
0.86	4.875	5.669
0.88	4.900	5.568
0.90	4.928	5.471
0.92	4.948	5.378
0.94	4.973	5.290
0.96	4.997	5.205
0.98	5.022	5.124
1.00	5.047	5.047

*From Consolazio, Johnson and Pecora (1963).

APPENDIX C

ENERGY EXPENDITURE FORMULAE

Resting Energy Expenditure:

$$\frac{\text{Resting metabolic rate}}{1 \text{ min}} = \frac{\text{O}_2 \text{ consumption (l)}}{5 \text{ min}} \times \text{caloric equivalent of R (5 min rest)}$$

$$\text{Resting Energy Expenditure (kcal)} = \frac{\text{Resting metabolic rate}}{1 \text{ min}} \times \text{total min. exercise and recovery}$$

$$\text{Net Energy Expenditure (kcal)} = \text{Gross Energy Expenditure (kcal)} - \text{Resting Energy Expenditure (kcal)}$$

$$\text{Energy Expenditure kcal/min (Gross and Net)} = \frac{\text{Energy Expenditure (kcal)}}{\text{Total exercise and recovery (min)}}$$

$$\text{Energy Expenditure kcal/kg}\cdot\text{hr}^{-1} \text{ (Gross and Net)} = \frac{\text{Energy Expenditure (kcal/min)}}{\text{Body Weight (kg)}} \times \frac{60 \text{ min}}{1 \text{ hour}}$$

$$\text{Energy Expenditure kcal/kg}\cdot\text{hr}^{-1} \text{ (Gross and Net)} = \frac{\text{Energy Expenditure kcal/min}}{\text{Lean Body Weight (LBW) kg}} \times \frac{60 \text{ min}}{1 \text{ hour}}$$

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