THE EFFECT OF LEG LENGTH DIFFERENTIAL ON AMBULATORY OXYGEN CONSUMPTION

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CHAPTER I

INTRODUCTION

The Twentieth Century has brought about phenomenal advances in technology and automation. The modern day computer age has significantly eliminated the muscular effort required in one's occupation. However, as in the past, man must still rely upon muscular energy and efficiency for play, recreation, and competition. Whenever there is human motion needed, the ability of the body to perform at optimal levels is desired. Too often man performs at certain levels without the knowledge of what may improve performance.

During the past decade there has been increased emphasis on physical fitness for purposes of health maintenance. As a result, interest has increased regarding optimum performance and efficiency of motion. Sports medicine research has revealed that maximal performance can be increased through the proper evaluation and correction of structural and postural deviations (29). Coaches and physical educators alike deal with athletes who, in spite of skills and physical attributes, may not be performing to full capacity due to an uncorrected physical deviation.

During recent years research efforts in physiology and rehabilitation have reflected an increased interest in the study of functional work capacity of both normal and handicapped populations regarding energy expenditure during ambulation. Research with these two populations has focused primarily on two areas: investigations to determine if the movement was performed in the most functional manner; and investigations to determine if the movement could have been performed in some equally effective but less exhaustive manner.

A substantial amount of research has been completed using oxygen consumption levels as indicators of energy expenditure. The measurement of oxygen intake levels has been considered by many physiologists to be an indicator of cardiovascular fitness. Since this measurement indicates how efficiently an individual's cardiovascular system adapts to the needs of ever increasing workloads, it is considered to be a valid criterion of physiological fitness. An activity becomes more efficient in terms of energy expenditure as the level of oxygen consumed decreases.

The literature contains numerous reports of research studies in the area of energy expenditure for different types of disabilities (1, 5, 9, 37, 47, 50-52). However, little research is available concerning work capacity relative to minor discrepancies in leg length. Pearson (41), in a study of 830 school children from 8 to 13 years of age, found that 93% had some degree of leg length asymmetry. Redler (44) found, in a study of 99 individuals complaining of pain in the lower back region, an average leg length difference range of from one-half to five-eighths of an inch.

Dean (11) found that the vertical displacement of the center of gravity increased when there was a discrepancy in leg length; therefore, when a limp was present, the energy cost was considerably higher than in persons having normal walking patterns. According to Molbech (37), persons having an abnormal gait used almost double the energy to move their body weight than did those having normal ambulatory patterns. Consequently, recreational and occupational tasks were performed at a higher energy expenditure.

Leg length asymmetries may be caused by either fractures, diseases, or spinal defects. Differences in length up to three-fourths of an inch may go undetected, since many individuals who are affected by abnormalities in gait often compensate with postural shifts so as to conceal the irregular pattern of ambulation. Although the gait pattern may not appear abnormal, continued performance in the presence of postural irregularities may prove costly in terms of energy expenditure.

The relationship of leg asymmetry to oxygen intake is of practical importance in a variety of occupational fields. The knowledge of the effects of leg length discrepancies becomes important when efficiency of movement in sports, physical activities, and occupational tasks are affected. The relationship of energy expenditure to limb length differential is of critical importance in athletic performance, in occupational work tasks, and in orthotic design (49).

The increased attention being directed to optimal efficiency output and minimal extraneous movement, coupled with the high incidence of leg length discrepancies (41), warrants the investigation of the relationship between energy expenditure and asymmetry in leg length. Specifically, little attention has been given to minor leg length discrepancies. Inequalities up to one-half inch are considered "normal," and usually go untreated. Therefore, it would appear that an investigation into energy requirements at this level of differentiation is warranted.

Statement of the Problem

The problem investigated in this study was the effect of leg length differential on the oxygen consumption level of ambulation. Specifically investigated was the effect of a one-half inch differential, a three-fourths inch differential, and zero differential, when ambulating on a treadmill at a constant workload. The workload was a treadmill speed of three miles per hour and an elevation of 16%.

Hypotheses

1. There will be no significant difference in oxygen consumption levels between a one-half inch differential in leg length and zero differential as measured at 5, 10, 15, and 20 minute time intervals.
2. There will be no significant difference in oxygen consumption levels between a three-fourths inch differential in leg length and zero differential as measured at 5, 10, 15, and 20 minute time intervals.
3. There will be no significant difference in oxygen consumption levels between a one-half inch leg length differential and a three-fourths inch leg length differential as measured at 5, 10, 15, and 20 minute time intervals.

Significance was accepted at the .05 level of confidence.

Limitations of the Study

1. The only attempt to regulate diet or activity prior to the testing was a request that the subject refrain from eating for three

to four hours before testing and that vigorous activity be limited for 24 hours prior to the testing.

2. The subjects were volunteers; therefore, the sample did not reflect a true random selection process.

Delimitations of the Study

1. The subjects were limited to 10 individuals who volunteered to particiapte in the study.

2. The artificially created differentials in leg length might have resulted in some psychological variability on the part of the subject.

3. The results may have been affected by some apprehension on the part of the subject due to the forced differential in leg length.

Assumptions

1. All subjects were motivated and exerted maximal effort during the testing procedure.

2. The shoes worn by the subjects had a negligible effect on the test results.

3. Any compression of the cork heel lifts during the testing procedure had a negligible effect on the test results.

4. Any training effect which might have occurred during the administration of the three tests had a negligible effect on the test results.

Definition of Terms

Aerobic. A process by which work is accomplished in the presence of oxygen.

Anaerobic. A process by which work is accomplished in the absence of oxygen.

Ambulation. To walk or move about; moving from place to place.

Atrophy. A decrease in size or a wasting away of a body part of tissue.

Disc Prolapse. Also called a rupture or herniation of the intervertebral disc with the nucleus pulposus extending through the annulus, usually in the posterior position.

Electrocardiography (*EKG*). A record of the electrical potential of the heart.

Gait. A manner of walking or moving on foot.

Kilocalories. A measure or work expenditure. VO of one liter per minute equals five kilocalories.

Lateral Asymmetry. A failure to correspond in size, shape, and relative position of opposite sides of the body.

Maximum Oxygen Consumption (*VO Max*). The maximal amount of oxygen an individual can consume when performing a given workload.

Maximal Work Test. A test capacity in which the subject must work to exhaustion at progressively increasing workloads.

Mechanical Abnormalities. Ambulation difficulties which arise from accidents or other traumas.

Minor Discrepancies. Those differences in leg length which, unless looked for, are unrecognizable. These do not require assistive devices.

Milliliters Per Kilogram of Body Weight Per Minute (Ml/kg/min). The unit for expressing maximal oxygen intake.

Nomogram. A graph which enables one to find the value of a dependent variable when two or more independent variables are known.

Normal Individual. An individual not suffering from inequalities in leg length due to vascular or traumatic injuries.

Percent Carbon Dioxide. The amount of carbon dioxide in the expired air.

Percent Oxygen. The amount of oxygen measured in expired air.

Physical Work Capacity (PWC). The maximum level of work of which an individual is capable. This is usually expressed as the amount of time required to reach a predetermined heart rate or work load.

Rate of Energy Expenditure. The amount of oxygen consumed per minute.

Relative Energy Cost. The rate of oxygen uptake divided by the individual's maximum ability to perform aerobic exercise.

Standard Temperature, Pressure, Dry (STPD). The values for correcting gas volumes to standardized conditions.

Submaximal Work Test. A work capacity test in which the subject does not have to work to exhaustion, but rather works to a predetermined workload or intensity.

Symes Vascular Amputation. The surgical procedure involving amputation of the foot-ankle joint and the removal of both malleoli.

Description of Instruments

Godart Pulmo-Analyzer. An instrument used to determine the percentage of carbon dioxide in samples of expired air.

Beckman Oxygen Analyzer. An instrument used to determine the percentage of oxygen in samples of expired air.

Nose Clip. A device used to close off the nostrils during breathing.

One-Way Breathing Valve. A device which enables the subject to take in atmospheric air and then to expel the air into a tissot tank for measurement.

Quinton Motorized Treadmill. An apparatus with a continuously moving belt that operates at various speeds and inclinations.

Sample Bags. One liter rubber bags used to hold samples of the subject's expired air.

Surface Electrodes. Devices attached to the skin surface to transduce the electrical impulses of the heart into electrical signals.

Tissot Tank. A large stainless steel tank which was used for the collection and measurement of expired air during work.

CHAPTER II

A SELECTED REVIEW OF LITERATURE

The literature contains many references to research reports measuring energy expenditure (Ee) for ambulation with different disabilities; however, there is a noticeable scarcity of research on oxygen intake and its relationship to leg length inequalities. This review is an attempt to summarize research findings for the measurement of Ee involving ambulation for normal subjects and for those with different disabilities. This review will be divided into two different phases: (1) a brief overview of the energy costs of normal walking; and (2) the effect of different lower extremity disabilities upon oxygen intake.

Energy Expenditure of Normal Ambulation

Numerous studies have been conducted in an attempt to derive relationships between energy expenditure and the variables that influence normal ambulation. Research has shown that Ee is influenced by such factors as the weight of the subject (3, 20, 21, 36), the gradient of the incline (3, 40), the speed of ambulation (3, 8, 35, 52), the training level (10, 15), age (14, 31), and sex (4, 16, 35, 52).

Booyens and Keatinge (4) report that the energy cost of women while walking to be as much as 12% less than that of men of equivalent weight. McDonald (35) observed that the energy cost was approximately 12% less for women than for men. However, contrary to these studies, Falls and Humphrey (16) and Ralston (42) found no difference between males and females.

Dill et al. (14) studied the influence of age on energy expenditure, and in a longitudinal study of one subject who repeated a walking experiment after a time interval of 25 years, found a significantly higher level of oxygen consumption. A slight decrease of Ee for walking after repeated performances of an experiment was reported by Knehr et al. (27), Erickson et al. (15), and Cotes and Meade (10). The explanation given was that training results in better coordination of movement, causing a slightly higher efficiency.

McDonald (15), in a review of literature from 1912 to 1958, noted that the Ee/unit distance walked varied only slightly at speeds of 60 to 80 meters per minute, but it was least at a speed of approximately 80 meters per minute, indicating this to be a comfortable, efficient walking speed. The average Ee/unit distance at 80 meters per minute was 0.0083 kcal/m/kg body weight for men and 0.0076 kcal/m/kg body weight for women.

Booyens and Keatinge (4) found that shorter stride lengths resulted in less lift work and, thus, caused a decrease in Ee. Cotes and Meade (10) determined that there was an optimum stride length for each speed and that lengthening or shortening the stride significantly caused increases in energy expenditure.

Bobbert (3), Corcoran and Brengelmann (8), and Ralston (42) showed that walking was most efficient at 78.8 meters per minute and that the comfortable walking speed chosen by the subjects approximated this speed. Waters et al. (52) found that normal subjects (87 men and 74 women) walked at an average speed of 82 meters per minute. This speed did not tend to vary with age; however, females expended significantly more energy per meter than did males. This contradicted the findings of several previously mentioned studies (4, 16, 41). Bard and Ralston (1) found that a subject, when allowed to walk at a speed that was either natural or comfortable, adopted a speed at which minimal Ee occurred. Margaria (32) analyzed oxygen consumption levels for normal subjects at various speeds and grades. It was shown that the optimum speed of walking occurred at approximately four kilometers per hour. Until walking speed varied greatly from this figure in one direction or the other, energy cost was not affected. Uphill walking was found to increase the energy demands on the body, while downhill walking required less energy than level walking.

Attention can now be turned to the disabled person and the factors which affect the efficiency of ambulation.

Energy Expenditure of Lower Extremity Disabilities

There has been a great deal of research done in the area of lower extremity disabilities. Studies with this population are extremely important, since the individual must attempt to ambulate as efficiently as possible while conserving energy and maintaining stability. The available literature was difficult to summarize due to the different levels of amputations studied, the small number of subjects used, the variations in speed of ambulation, and the variations in experimental procedures employed.

In the only study which dealt specifically with Symes amputees, Waters et al. (52) found that this group of individuals walked at an average of 54 meters per minute, which was 34% less than normal controls, who averaged 84 meters per minute. However, the Symes amputees expended a substantially higher amount of energy at this slower speed. This would indicate that a slower speed does not always imply a more efficient expenditure of energy.

In 1971, Ralston (42) studied the energy cost of two below the knee (BK) amputees walking at various speeds and compared this to the energy cost of normal subjects walking at the same speeds. The Ee per unit time of the unilateral BK amputees walking at a chosen speed of 48.8 meters per minute was slightly less than that of normal subjects walking at a comfortable speed of 73.2 meters per minute. However, when the amputees attempted to walk at speeds which were comfortable for the normal subjects, the energy expenditure per step was substantially higher. It was therefore concluded that, when allowed to choose the speed of ambulation which is most comfortable, the energy cost per minute is similar in amputees and in normal subjects.

Gonzalez et al. (19) studied nine BK amputees, all of whom were over 40 years of age. The subjects walked at various speeds ranging from 33 to 91.2 meters per minute. The average comfortable walking speed for normals in this study was 83.1 meters per minute, which equaled 0.063 kcal/min/kg of body weight. The amputees ambulated at a chosen speed of 64.4 meters per minute, or 22% slower than the normal control group. The Ee, however, was 0.062 kcal/min/kg body weight, indicating energy expenditure per minute was approximately the same for the amputees and the controls, even though the speed was substantially slower.

A treadmill study performed by Molen (38) compared energy expenditure of BK amputees and normal subjects at various speeds, ranging from 50 to 90 meters per minute. At all speeds, an average of 20% more kcal/min was expended by amputees than by the control group walking at the same speeds.

Waters et al. (52) compared the energy cost of walking in normal subjects and in patients with unilateral traumatic and vascular amputations. The normal subjects' mean energy expenditure was calculated to be approximately 2.5 ml/kg/min lower than the mean oxygen uptake for the amputee population. When patients were grouped according to the level of amputation, it was concluded that the energy cost of walking decreased as the level of amputation was lowered.

Ganguli (18) studied the energy cost of normal subjects and amputees who used axillary crutches. A walking speed of 50 meters per minute was chosen as a constant rate of movement. The subjects utilizing the axillary crutches required 46.5% more kcal/minute than did the normal subjects. This study also compared the energy expenditure of patients using a prothesis to those using the crutches. At the same speed of 50 meters per minute, 35% more energy was required for the group ambulating with the prothesis. This was attributed to the amount of energy required to lift the heavier weight created by the prothesis.

Traugh et al. (50) tested nine subjects having above the knee (AK) amputations to determine the type of assistive device which would demand the least amount of energy. In contrast to the work done by

Ganguli (18), it was determined that crutch walking and prothestic ambulation required the same amount of energy. The study also found that normal subjects walking at speeds of nearly twice that of the amputee patients required approximately 65% less energy. A lesser difference of energy cost between the AK individual and the normal individual was found by Waters et al. (52). The relative energy cost of the AK amputees was 63%, compared to the normal population's expenditure of 38%.

James (25) reported that 37 AK amputees, ages 21 to 62, chose speeds of ambulation that were 30% slower than the speeds selected by the normal control group. However, the energy expenditure per unit distance was 40% higher for the amputees than for the normals.

It would appear that a great deal of discrepancy results in discussing the average energy expenditure for the amputee. The studies did agree that an optimum speed exists at which the least and the most efficient energy expenditure occurs. However, because of differences in measurement criteria--Ee/unit time, Ee/unit step, and Ee/unit distance--the data were hard to compare. Some studies tended to be biased in that the researcher based the results on the abulating speeds chosen by the subjects rather than using speed as an independent variable in the study.

Veicsteinas et al. (51) studied the energy cost of walking in patients affected by chronic lesions of the foot that resulted in a limp. According to the specific lesion, the patients were divided into three groups: Group A had lesions of the hind part of the foot and suffered from either trimalleolar or calcaneal fractures resulting in pain and decreased motion; Group B had lesions of the middle of the foot, pes cavus, pronation, and club foot, all resulting in moderate to severe pain during activity; and Group C had lesions of the fore part of the foot, hallux valgus. The investigation revealed that only the subjects in Group B showed an increased energy cost that amounted, on the average, from 5 to 20% while walking uphill. The higher the speed of walking, the greater the increase in energy cost. With only a few exceptions, the energy costs in both Groups A and C fell within normal limits.

Imms et al. (24) compared oxygen consumption during walking in 13 subjects recovering from fractures of the leg to the oxygen consumption of eight control subjects. The subjects walked at velocities of 0.5, 1.0, and 1.5 meters per second. The control group had readings of 8.0, 9.8, and 13.6 ml/kg/min., respectively. For subjects walking on crutches with the leg encased in a Plaster of Paris cast, the oxygen consumption at these speeds was 12.0, 17.5, and 25.3 ml/kg/min. The energy cost of walking was reduced when the cast was removed, when the crutches were replaced by canes, and when all aids were eventually discarded. The energy expenditure was normal at 0.5 and 1.0 meters per second, but was still significantly higher at the faster velocity of 1.5 meters per second.

Molbech (37) studied 24 subjects suffering from a variety of conditions that resulted in a limp or other abnormal walking pattern. Subjects were divided into four groups: cerebral paresis, poliomyelitis, disc prolapse, and a group with mechanical conditions (such as fractures) in the lower extremities. The test results were based on oxygen consumption levels and on maximum isometric muscle strength. The subjects with cerebral paresis had somewhat reduced leg strength but showed almost no muscular asymmetry. All subjects recovering from polio had strength reduction and muscular asymmetry. In this group, variations in paralysis and in loss of active muscle strength resulted in variations in both strength and working capacity. Statistically, no conclusions could be drawn on the basis of the results obtained from the subjects with disc prolapse. The physiological working capacity of this group was evaluated; however, the pain experienced upon assessment of leg extension strength was too severe to permit conclusions to be drawn. The group described as having abnormal biomechanical conditions in the lower extremities was very heterogeneous. One subject showed signs of equinus, another had leg length asymmetry, and three patients had fractures of the leg itself. The abnormal conditions of this group seemed to cause a marked increase in ambulation cost attributed to pain and possibly to psychological factors.

DeLacerda and McCrory (12) found marked elevations in oxygen consumption when comparing submaximal test results of a subject with a 28.6 millimeter leg length differential. The subject was tested at a treadmill speed of 5.47 kilometers per hour and at elevations of 16 and 20%. Each test was performed with the asymmetry present and with the use of a heel lift that equalized the leg length. On each submaximal test, the oxygen consumption was less when the leg lengths were equalized.

Another study performed with the same subject by DeLacerda and Wykoff (13) showed that equalization of leg length also improved the biomechanical function and efficiency of ambulation for both legs as determined by kinetic energy analysis of a complete four cycle gait pattern.

Imms et al. (24) studied a patient recovering from a fracture of the shaft of the femur which resulted in a five centimeter shortening of the injured leg. The subject's leg length had been equalized through the use of an orthotic shoe. Energy expenditure was less when walking in this shoe than when walking in a standard shoe with no correction. Observation of the subject revealed that the increased lift brought about by the difference in leg length elevated the Ee during walking, and the correction with a built-up shoe lowered the Ee.

Simonson and Keys (47) investigated the energy expenditure of two poliomyelitis patients, one clinically recovered from paralysis (E.B.); the other (J.D.) with an atrophic leg which was 11 centimeters shorter than the left leg. The energy expenditure was compared to that of two normal subjects while walking on a treadmill at different speeds and inclines. The Ee of E.B. coincided with normal values at all variations of speed and grade, up to 3.5 miles per hour. J.D.'s energy expenditure when walking with braces exceeded the normal values 1.5 to 2.6 times at all variations investigated.

Hemiplegia obviously affects many factors which are involved in normal walking patterns. As more and more of these factors become involved, more energy is demanded for ambulation. Corcoran et al. (9) studied 15 hemiparetic subjects with and without braces. The average comfortable walking speed without bracing was 41 meters per minute, which was 46% slower than the 83 meters per minute speed used by the normal control group. The hemiparetic used 64% more energy expenditure per unit of time at this speed than did normal subjects at the same speed. With bracing, the speed of walking improved 17% to 49 meters per minute, and the Ee/unit time was also significantly reduced. According to Corcoran's data, the hemiplegic expended approximately the same kcal/unit time walking at 41 meters per minute as a normal subject expended at 83 meters per minute. In terms of Ee/unit distance, the average braced hemiplegic walked comfortably at a speed of 49 meters per minute and used 55% more Ee/unit distance than did a normal subject walking at a comfortable speed of 83 meters per minute.

Bard and Ralston (1) reported studies with three hemipletics. One subject had a comfortable return of function to the right side following a cerebral vascular accident, and had an energy expenditure that was actually less than that of normal subjects up to a speed of 73 meters per minute. A second subject, requiring a brace and a cane, could walk only at 28 meters per minute. The Ee/unit distance fell within normal limits. The third subject, using only a cane, walked at 49 meters per minute, and utilized 25% more Ee/unit distance than did the normal person.

Clinical experience with the paraplegic suggested that intensity of muscular work was greater than in other lower extremity disabilities. The added loss of function encountered by a parapletic obviously results in elevated energy cost. Long and Lawton (28) believed that, although neurologically involved subjects with lesions at the T1 -T11 levels could ambulate with bracing and crutches, ambulation was not functional, whereas T12 patients were considered functional ambulators.

Gordon and Vanderwalde (21) studied 11 paraplegics, finding the energy expenditure of walking at 27 meters per minute to be 580% more than the basal kcal/minute expenditure. A normal person walking at 73 meters per minute expended 430% more energy than at the basal rate (8). As the speed of ambulation increased, so did the energy expenditure. Gordon concluded from the study that while patients with cord lesions above T12 could ambulate, it would be done at tremendous energy costs. Also, the extreme physiological stress placed on the paraplegic while attempting to ambulate made it impractical, since ambulation could not be maintained for a long enough time to cover any significant distances.

It would appear from this review that energy expenditure and efficiency of movement are significantly elevated in subjects who are affected by various disabilities in the lower extremities. One of these disabilities which has yet to be studied has to do with minor leg length differentials.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine the effect of differences in leg length on ambulatory oxygen consumption at submaximal workloads. Specifically tested were leg length differences of one-half inch, three-quarters inch, and zero.

Selection of Subjects

The subjects in this study consisted of 10 females ranging in age from 22 to 48. The subjects were volunteers and were graduate students enrolled in physical education classes at Oklahoma State University. All subjects were involved in individual aerobic exercise programs; however, no attempt was made to match the cardiovascular fitness level of the subjects.

Determination of Leg Length Differential

The examiner determined the actual leg length of each subject by using a plumb line to measure the distance from the anterior-superior spine of the pelvis to the sole of the foot. The spine of the pelvis was palpated with the subject in a standing position, with the top of the plumb line held by the examiner at that point. The line then fell in a straight line past the medial aspect of the knee joint and directly in front of the medial malleolus of the ankle. The measurement was taken from the palpated anterior-superior spine to the point where the weight at the end of the plumb line touched the floor. These two points determined the leg length that was then measured to the nearest one-sixteenth of an inch against a metal tape secured to a flat top table. Upon determination of the subject's leg length, the above described measurement was validated by comparison with a basic procedure outlined by Redler (44) using the posterior iliac spines as the reference points for measurement. The subject's posterior iliac spines were located by palpation, and the examiner's hands were placed on each crest to determine any difference in height. Calibrated blocks of balsa wood of one-sixteenth inch thickness were then progressively placed beneath the heel on the low side until the spines were level. The thickness of the lift needed in order to level the posterior spines determined the amount of asymmetry. This measurement was then compared to the amount of difference as determined by the plumb line method. Upon determination of the amount of asymmetry present, the investigator determined the amount of lift necessary to create each of the three conditions to be tested: zero, one-half inch, and three-quarters inch.

Test Procedure

The subjects reported to the Oklahoma State University Human Performance Laboratory dressed in activity clothes and jogging shoes. The age, height, and weight for each subject was recorded. A cork lift was inserted into the heel of the appropriate shoe in order to to create artificially one of the three variables to be tested. The order of variables tested was randomly selected in order to counterbalance any differences which might occur due to either training or familiarity with the testing procedure. The subject was aware of the differential being tested.

Three skin electrodes were placed on the upper sternum and lower left rib cage areas. EKG leads were attached and connected to a Birtcher ECG machine, allowing the heart rate to be constantly monitored throughout the test. At this time, the subject was given time to practice breathing through the one-way valve with the nose clip in place. The subject was instructed to sit quietly for five minutes in order for the heart rate to stabilize. After a resting heart rate was determined, a two minute resting pulmonary gas sample was collected in the Collons Tissot tank and analyzed for oxygen and carbon dioxide content using a Beckman Oxygen Analyzer and a Godart Pulmo-Analyzer.

Prior to the actual treadmill test, each subject was allowed to observe a demonstration of the correct procedure to be used in mounting and dismounting the treadmill. Subjects, without practice, mounted the treadmill, and as soon as a normal walking pace had been established, the test was begun. Subjects walked at three miles per hour and at a constant grade of 16%. Gas samples were collected during the last 30 seconds of each 5 minute interval for a total treadmill duration of 20 minutes. Air samples were transferred from the tissot tank to the analyzing equipment in one liter rubber bags for the determination of oxygen and carbon dioxide content. The Beckman Oxygen Analyzer and the Godart Pulmo-Analyzer were calibrated against a known gas sample composed of 15% oxygen and 6% carbon dioxide. Oxygen consumption was calculated for each five minute sample using the open circuit method as described by Ricci (45). Temperature was recorded from a gauge attached to the top of the tissot tank, and the barometric pressure was read from a barometer located in the Human Performance Laboratory. The temperature correction factor was determined by using a nomogram.

At the completion of the 20 minute time period, the subject dismounted the treadmill and sat on a bench for approximately five minutes. The heart rate was monitored during this time to insure that it was returning to the resting level.

This test procedure was repeated three times, with the control variable being the amount of leg length differential. Each subject completed the series of three tests within a 10 day period of time, with at least a 48 hour interval between tests. Each subject was tested at approximately the same time of the day to account for any circadian differences that may exist. The only attempt to control either the diet or the activity of the subject was the request that vigorous exercise be limited for 24 hours prior to the testing and that food intake be restricted for three hours.

Analysis of Data

Using the statistical program described in *Statistical Package for the Social Sciences* (*SPSS*) (39), the data were subjected to a Single Way ANOVA--Repeated Measures Design. The collected data were coded, keypunched, and submitted for treatment and analyzation at the University of Tulsa Computer Center. By comparing the means of each of the three variables at each of the four time intervals, it was possible to determine any significant differences which occurred due to the treatment employed. Significance was accepted at the .05 level of confidence. Further explanation and discussion of this statistical procedure is explained in Chapter IV.

CHAPTER IV

RESULTS AND DISCUSSION

A total of 10 graduate students at Oklahoma State University participated in a study to determine the effect of leg length differential on ambulatory oxygen consumption levels. Subjects were tested at submaximal exercise levels at each of three conditions: zero differential, one-half inch differential, and three-fourths inch differential.

Descriptive Data

The 10 subjects ranged in age from 22 to 48 years. The height, weight, and leg length for each subject are shown in Table I. Leg length differences ranged from one subject who showed a one-half inch differential, to one subject who was measured as having no difference in length. The right leg was shorter in six of the subjects, while the left leg was shorter in three subjects. One subject had even leg lengths. These figures deviated from the results reported by Redler (44), in which the left leg was found to be shorter in 80 out of 99 patients measured. However, due to the small number of subjects used, this would not appear to be too extreme a departure from the norm.

TABLE I

HEIGHT, WEIGHT, AND LEG LENGTH OF SUBJECTS

Subject	Ht(cm)	Wt(kg)	Rt. Leg(cm)	Lt. Leg(cm)	Difference(cm)
1	160.02	56.81	93.66	94.23	.57
2	172.72	59.09	99.37	100.65	1.28
3	168.91	54.54	96.77	97.47	.70
4	165.10	56.81	93.03	93.35	.32
5	171.45	61.36	99.31	100.01	.70
6	170.18	56.81	94.23	93.98	.25
7	173.99	71.36	102.87	102.87	.00
8	170.18	65.90	98.43	97.79	.64
9	160.02	57.27	91.76	91.44	.32
10	162.56	55.00	95.25	95.57	.32
N=10	$\bar{X}$=167.51 SD= 5.03	$\bar{X}$=59.50 SD= 5.01	$\bar{X}$=96.47 SD= 3.25	$\bar{X}$=96.74 SD= 3.35	$\bar{X}$=.51 SD=.64

Measurements and Standard Deviations of Oxygen Consumption

Each subject's oxygen consumption was calculated at five minute intervals during the 20 minute submaximal test. The exact oxygen consumption readings from each subjects are depicted in Tables II-IV.

TABLE II

OXYGEN CONSUMPTION (ml/kg/min), ZERO DIFFERENTIAL

Subject	5 Minute	10 Minute	15 Minute	20 Minute
1	33.72	37.82	38.26	40.16
2	20.48	30.02	37.04	40.66
3	24.68	32.28	33.57	41.85
4	29.67	35.44	39.75	38.11
5	27.37	33.34	38.57	40.57
6	28.43	31.64	33.66	35.16
7	29.71	32.00	32.00	37.00
8	33.46	37.40	38.43	37.23
9	31.80	36.24	31.55	30.46
10	28.54	40.23	42.78	38.14
N=10	$\bar{X}$=28.786 SD= 4.01	$\bar{X}$=34.641 SD= 3.38	$\bar{X}$=36.561 SD= 3.69	$\bar{X}$=37.934 SD= 3.33

TABLE III

OXYGEN CONSUMPTION (ml/kg/min), ONE-HALF INCH DIFFERENTIAL

Subject	5 Minute	10 Minute	15 Minute	20 Minute
1	23.99	30.14	28.31	36.04
2	28.00	36.19	40.96	37.22
3	25.28	27.81	33.64	34.12
4	38.60	40.76	42.27	45.56
5	31.32	34.13	40.82	48.95
6	25.16	35.39	34.44	35.49
7	26.44	34.29	35.44	38.07
8	33.40	36.69	38.27	42.64
9	44.10	40.50	37.83	40.00
10	30.64	33.45	40.06	46.13
N=10	$\bar{X}$=30.694 SD= 6.50	$\bar{X}$=34.935 SD= 4.04	$\bar{X}$=37.204 SD= 4.18	$\bar{X}$=40.422 SD= 5.12

As can be seen in Table II, the mean oxygen consumption for the zero differential was 28.79 ml/kg/min. The figures increased at each 5 minute interval, with a mean 20 minute oxygen consumption reading of 37.93 ml/kg/min. The increase of oxygen intake from the 5 minute reading to the 10 minute reading was the greatest. This increase, from 28.78 ml/kg/min to 34.64 ml/kg/min, might be attributed to the subjects' initial acclamation physically and mentally to the treadmill. The stabilization which occurred at the 15 and 20 minute intervals represents the attainment of a somewhat more steady state. The differences between the 10 and 15 and the 15 and 20 minute intervals were 1.92 ml/kg/min and 1.37 ml/kg/min, respectively. Slightly lower figures at this same differential, speed, and grade were reported by DeLacerda and McCrory (12). However, it must be noted that the subject in this case study was involved in a very extensive running program, which might account for the lower oxygen consumption readings.

Table III depicts the oxygen consumption readings with the one-half inch leg length differential. The mean 5 minute reading was 30.69 ml/kg/min, which was slightly higher than that same reading for the zero differential. The mean readings at the one-half inch differential increased steadily throughout the test, with the 20 minute calculation being 40.42 ml/kg/min. The increases between the time intervals were somewhat more regular than in the zero differential. In order for this difference not to be affected by familiarity with either the testing procedure or with the equipment itself, the order of testing was randomized.

Table IV indicates the oxygen consumption readings for each subject at the three-fourths inch differential. The means for each of the four different time intervals once again show a steady increase in oxygen consumption as the time on the treadmill increased. This increase is a natural and expected one, in that as exercise continues over an extended period of time, the energy demand on the cardiovascular system increases. This increase in oxygen consumption as a function of time has been shown to occur in various physiological studies.

TABLE IV

OXYGEN CONSUMPTION (ml/kg/min), THREE-FOURTHS INCH DIFFERENTIAL

Subject	5 Minute	10 Minute	15 Minute	20 Minute
1	25.70	27.40	37.67	53.27
2	34.23	32.45	33.76	33.30
3	25.51	29.27	35.71	37.24
4	33.07	43.51	44.81	51.43
5	39.81	49.88	59.30	61.66
6	33.29	34.26	36.15	37.22
7	31.62	35.62	36.50	35.10
8	41.41	38.97	41.56	48.11
9	32.87	43.14	47.67	48.48
10	29.99	38.48	38.49	38.41
N=10	$\bar{X}$=32.750 SD= 5.15	$\bar{X}$=37.298 SD= 6.94	$\bar{X}$=41.162 SD= 7.71	$\bar{X}$=44.411 SD= 9.46

The mean difference in readings did increase between each of the three variables tested at all four time intervals. The smallest increase occurred at the 10 minute interval between the zero differential (34.64 ml/kg/min) and the one-half inch differential (34.94 ml/kg/min). The greatest difference occurred at the final reading of 20 minutes between the one-half (40.42 ml/kg/min) and the three-fourths

(44.42 ml/kg/min) differential. This increase might be speculated to occur due to the fact that this level of oxygen intake is in the range of high intensity workloads. Therefore, as the subjects approach higher levels of exercise, the energy expenditure becomes more affected by the increased leg length differential. This same increase can also be seen to lesser degrees in every other measurement. This trend would seem to substantiate the idea that as the leg length differential increased, the oxygen consumption level increased.

Analysis of Variance Between Groups

To determine significance between the three variables at each of the four time intervals, the data were subjected to four separate Repeated Measures ANOVA Designs. The results of these procedures are located in Tables V-VIII. Table V depicts the analysis of variance between the three variables at the five minute interval. The F ratio of 1.88 was not significant at the .05 level of confidence. Therefore, the null hypothesis of no significant difference among the three variables at the five minute time interval was accepted.

The information in Table VI deals with the analysis of variance among the zero differential, the one-half inch differential, and the three-fourths inch differential at the 10 minute time interval. The F value of 1.19629 was determined not to be significant at the required level of .05. Therefore, the null hypotheses of any significant difference at this time interval was accepted.

The calculations in Table VII illustrate the difference which occurred at the third time interval of 15 minutes. The probability of

TABLE V

ANALYSIS OF VARIANCE TABLE - COMPARISON OF THREE VARIABLES AT FIVE MINUTE INTERVAL

	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability Level
Between People	386.77	9	42.97		
Within People	455.42	20	22.77		
Between Measures	78.60	2	39.30	1.88	.18174
Residual	376.82	18	20.93		
Total	842.18	29	29.04		

TABLE VI

ANALYSIS OF VARIANCE TABLE - COMPARISON OF THREE VARIABLES AT 10 MINUTE INTERVAL

	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability Level
Between People	357.49	9	39.74		
Within People	361.67	20	18.08		
Between Measures	42.43	2	21.22	1.19629	.32524
Residual	319.23	18	17.73		
Total	719.16	29	24.80		

.08839 was not significant for the F ratio of 2.78436, but was considerably closer than either of the above two calculations. However, statistically the null hypotheses of significance at this time level was accepted.

TABLE VII

ANALYSIS OF VARIANCE TABLE - COMPARISON OF
THREE VARIABLES AT 15 MINUTE INTERVAL

	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability Level
Between People	422.03	9	46.89		
Within People	525.49	20	26.27		
Between Measures	124.16	2	62.08	2.78436	.08839
Residual	401.33	18	22.30		
Total	947.53	29	32.67		

As can be seen in Table VIII, the probability figure of .06140 for the 20 minute time interval was the closest significance which was found in the four tests. However, the F ratio of 3.27135 still did not prove to be significant statistically. The null hypotheses for significance at the 20 minute time interval was accepted. The fact that significance increased as the duration of the exercise increased would tend to indicate that the metabolic demands placed upon the body's system physiologically causes a proportionately greater requirement for oxygen. It is possible to speculate that the difference in leg length could be a more prominent factor in oxygen consumption as the subject reaches a higher degree of performance as measured by time.

TABLE VIII

ANALYSIS OF VARIANCE TABLE - COMPARISON OF THREE VARIABLES AT 20 MINUTE INTERVAL

	Sum of Squares	Degrees of Freedom	Mean Square	F	Probability Level
Between People	550.79	9	61.20		
Within People	803.80	20	40.19		
Between Measures	214.28	2	107.14	3.27135	.06140
Residual	589.52	18	32.75		
Total	1354.59	29	46.71		

A three-by-four factor ANOVA was performed to determine any difference which might exist from the interaction among the four time intervals and the three control variables. The results of this calculation are found in Table IX. As can be noted, the only significance found was that which occurred as the time intervals increased. This was a difference which was expected to exist in that, as exercise duration increases, the amount of oxygen required increases. However, this significance did not have a direct bearing on the problem being studied, since the control variable was the leg length differential and not the time factor. The other two differences tested, leg length differential and the interaction of the time intervals and the differential, proved not to be significant with F ratios of 1.0125 and .0520, respectively.

TABLE IX

ANALYSIS OF VARIANCE TABLE - COMPARISON OF INTERACTION OF TIME INTERVAL AND LEG LENGTH DIFFERENTIAL

	Sum of Squares	Degrees of Freedom	Mean Square	F	Critical F(.05)
Total	15628.29	119			
Subjects	1261.48	9			
Retention (Time)	1701.83	3	567.26	33.62	2.96*
Difficulty (Levels)	412.73	2	206.365	1.0125	3.55
Difficulty Times Retention	46.75	6	7.791	.0520	2.30

*p is significant at the .05 level of confidence.

Graphs of Individual Subjects

Although significance was not found to exist for the variables tested, it is interesting to observe the findings of the 10 subjects studied. Looking at Figures 1-10, three distinct patterns can be seen. Figures 1-4 show an increase in oxygen consumption levels as the difference in leg length increases. Based on the small number of subjects used in this study, the results of the findings in Figures 1-4 might be indicative of a larger population. As can be seen in these first four graphs, the increases vary a great deal from individual to individual. This, however, should be expected due to the fact that the fitness levels of each subject were not taken into account in the study. Figure 1 depicts the most extreme difference in oxygen consumption levels. The subject at the completion of the 20 minute submaximal test showed a zero differential reading of 40.57 mg/kg/min, a one-half inch differential of 48.95 ml/kg/min, and a three-fourths inch differential of 61.66 mg/kg/min. This last reading would indicate a very intense workload. The difference from zero differential to three-fourths inch differential of 21.09 ml/kg/min would seem to indicate that the energy expenditure of this particular subject increased substantially as the differential in leg length increased. The results of Figures 2-4 show increases at each level of differentiation at somewhat lesser extremes. It should be noted that in 4 out of the 10 subjects tested, these increases did occur. The leg length differential must be considered an influencing factor.

The oxygen consumption readings found in Figures 5-7 depict results which are not as well defined. The highest levels of oxygen

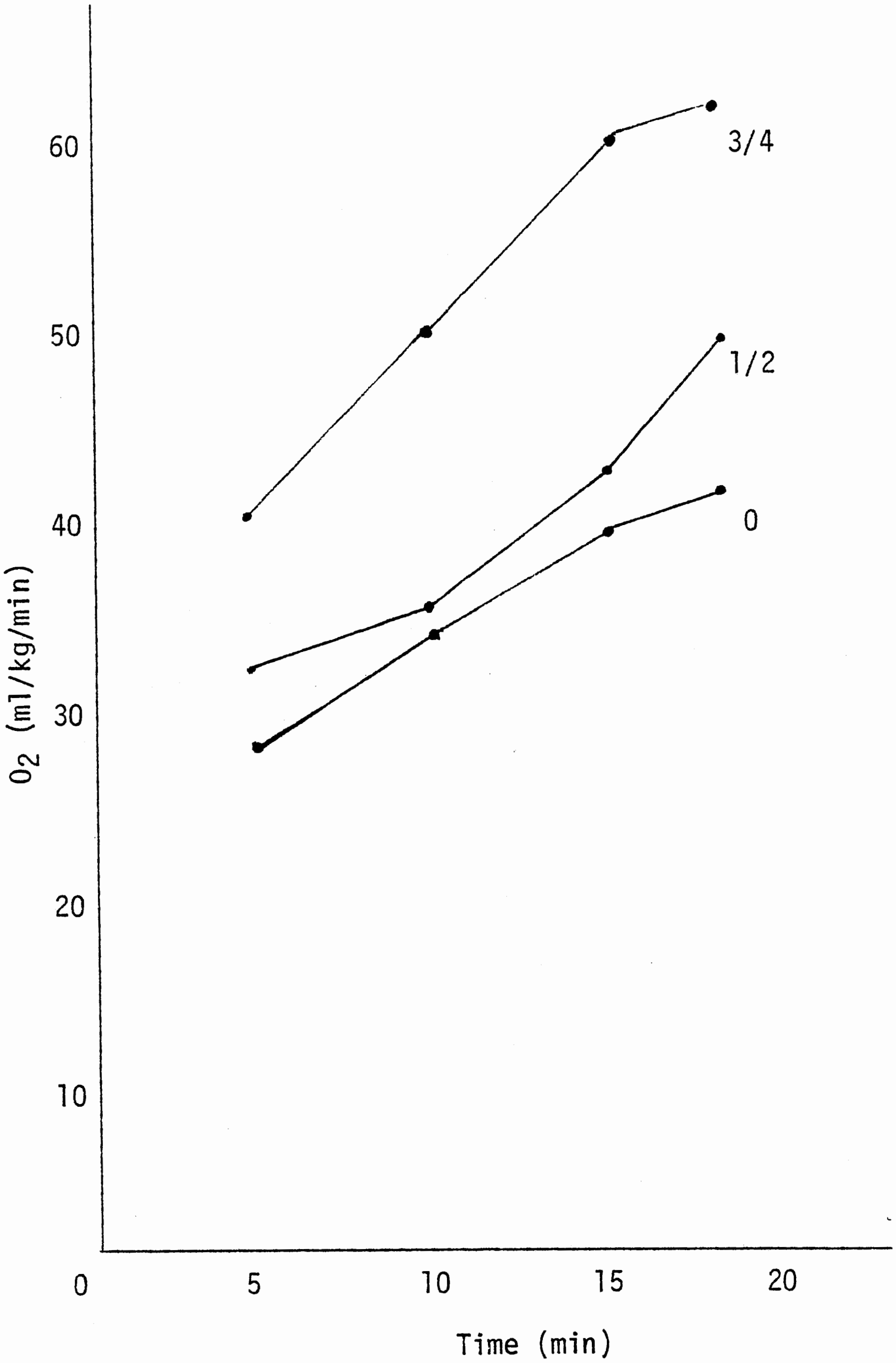

Figure 1. Oxygen Consumption of Subject #5 at Three Leg Length Variables

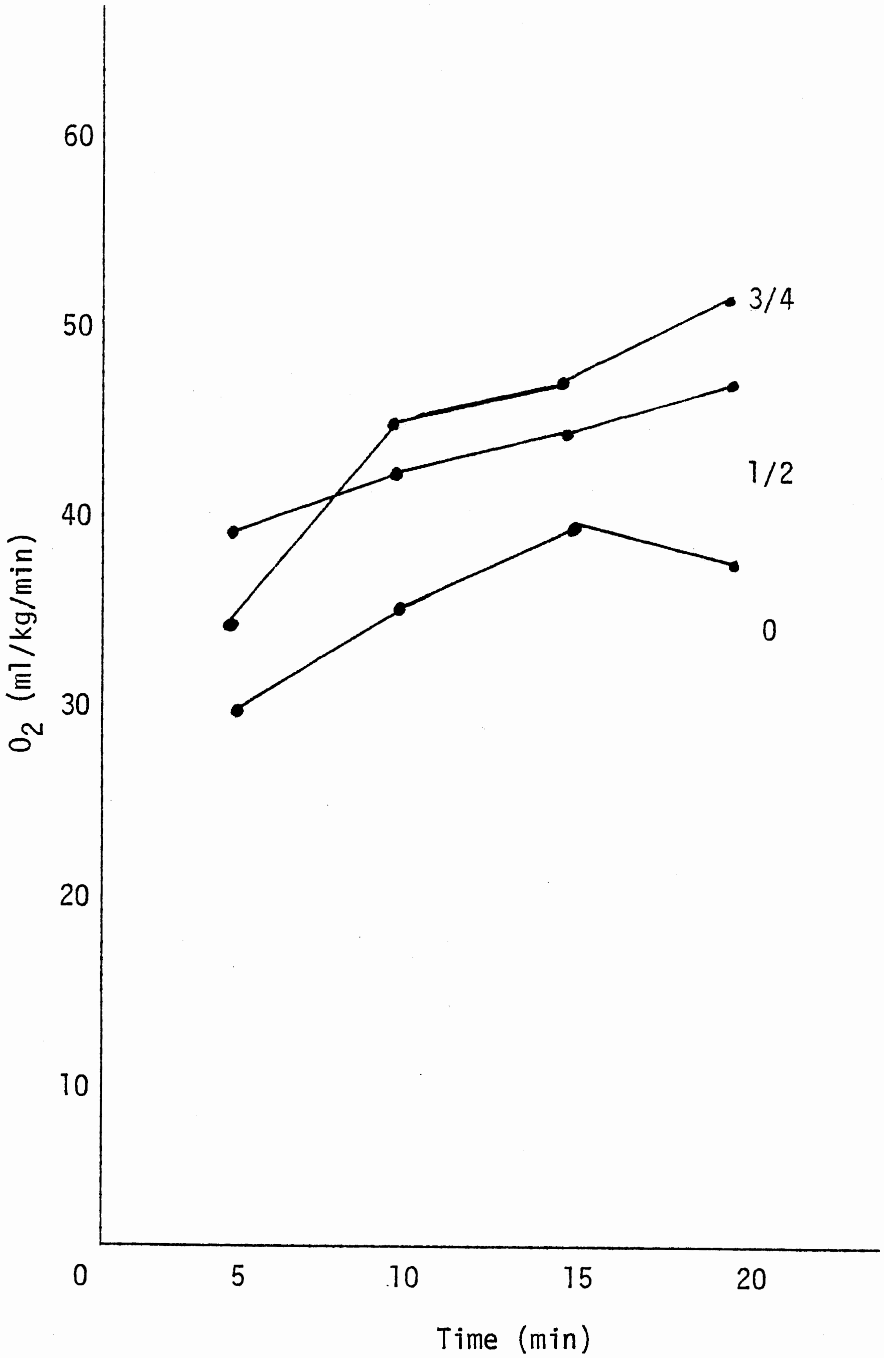

Figure 2. Oxygen Consumption of Subject #4 at Three Leg Length Variables

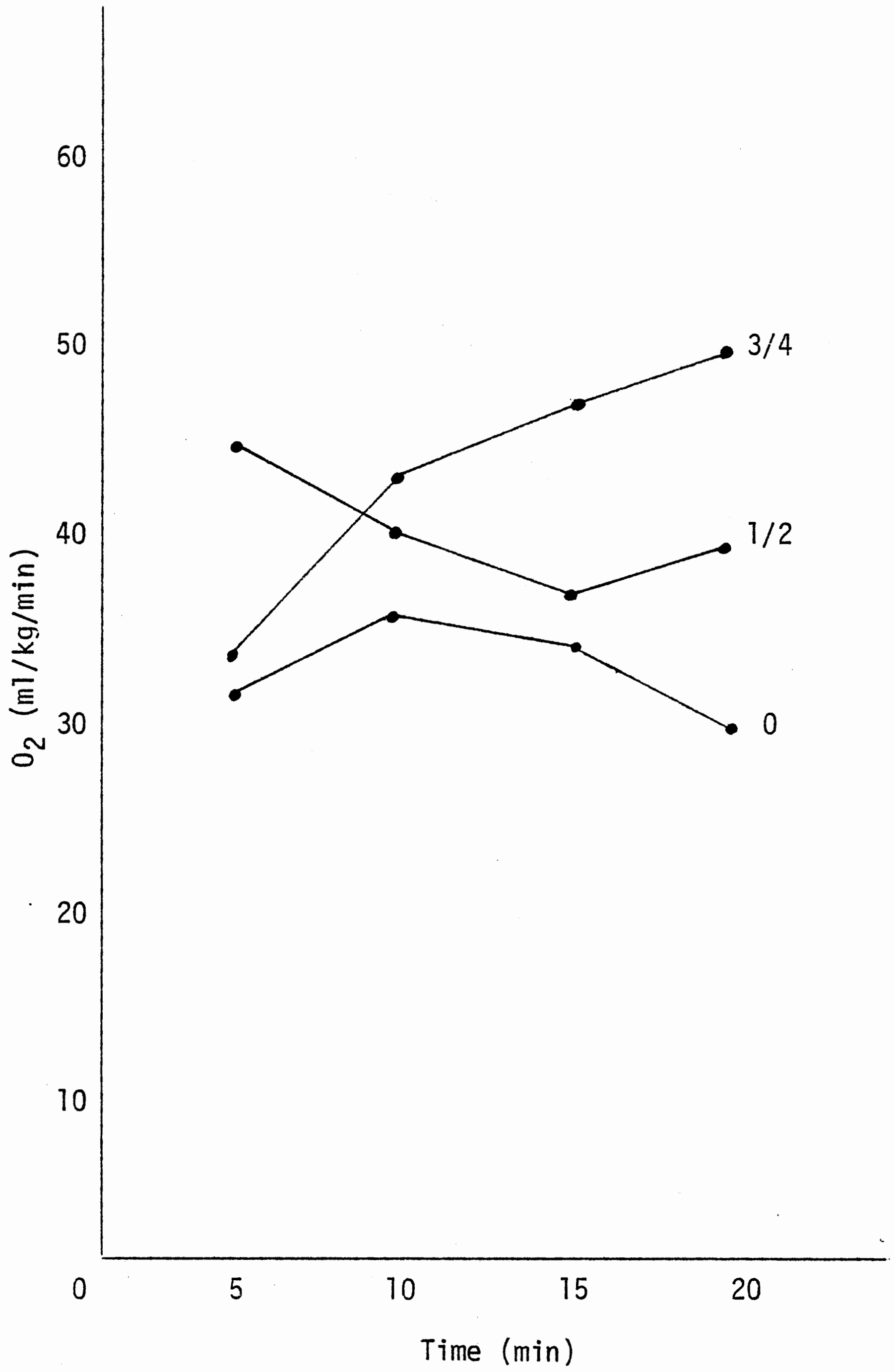

Figure 3. Oxygen Consumption of Subject #9 at Three Leg Length Variables

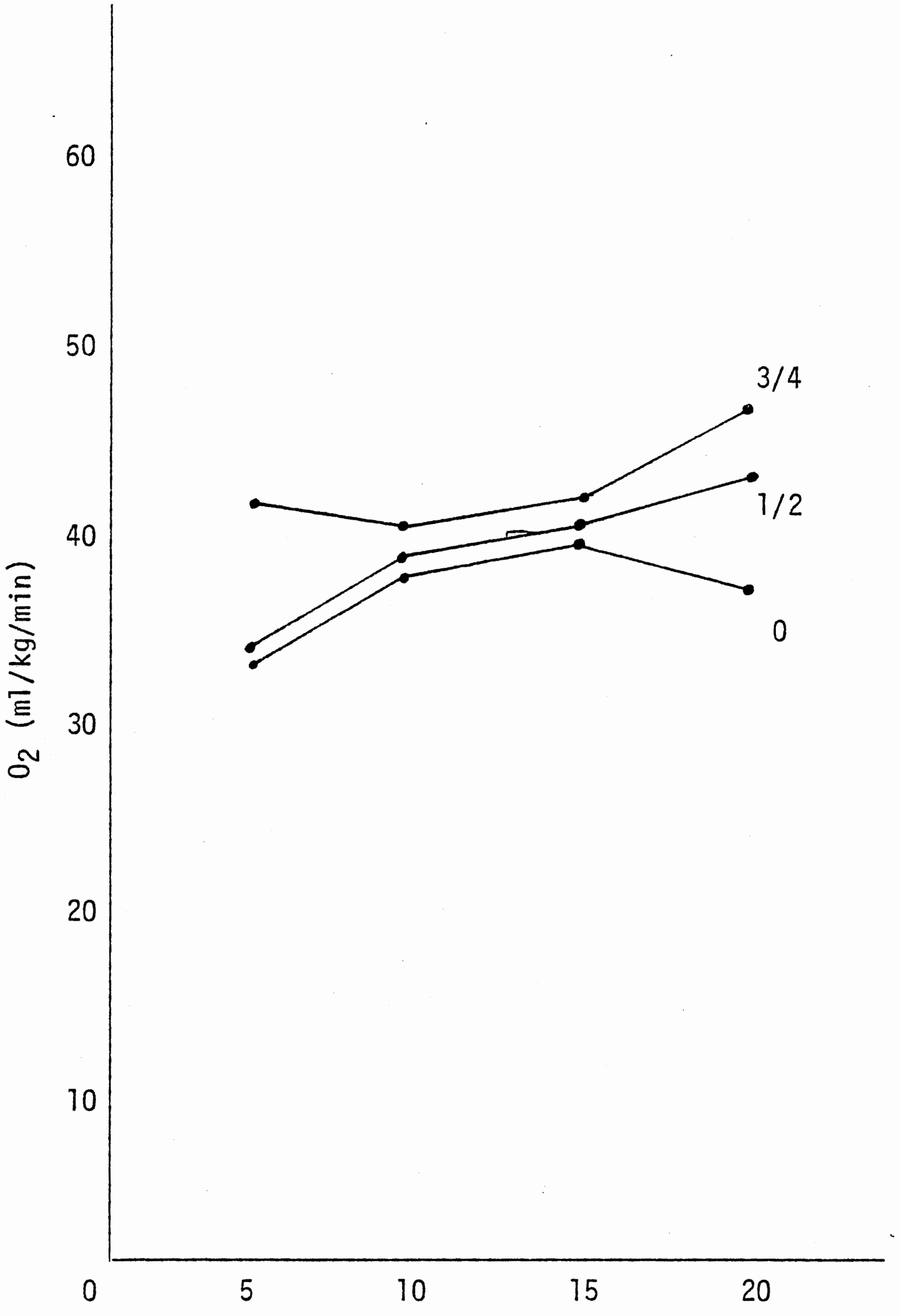

Figure 4. Oxygen Consumption of Subject #8 at Three Leg Length Variables

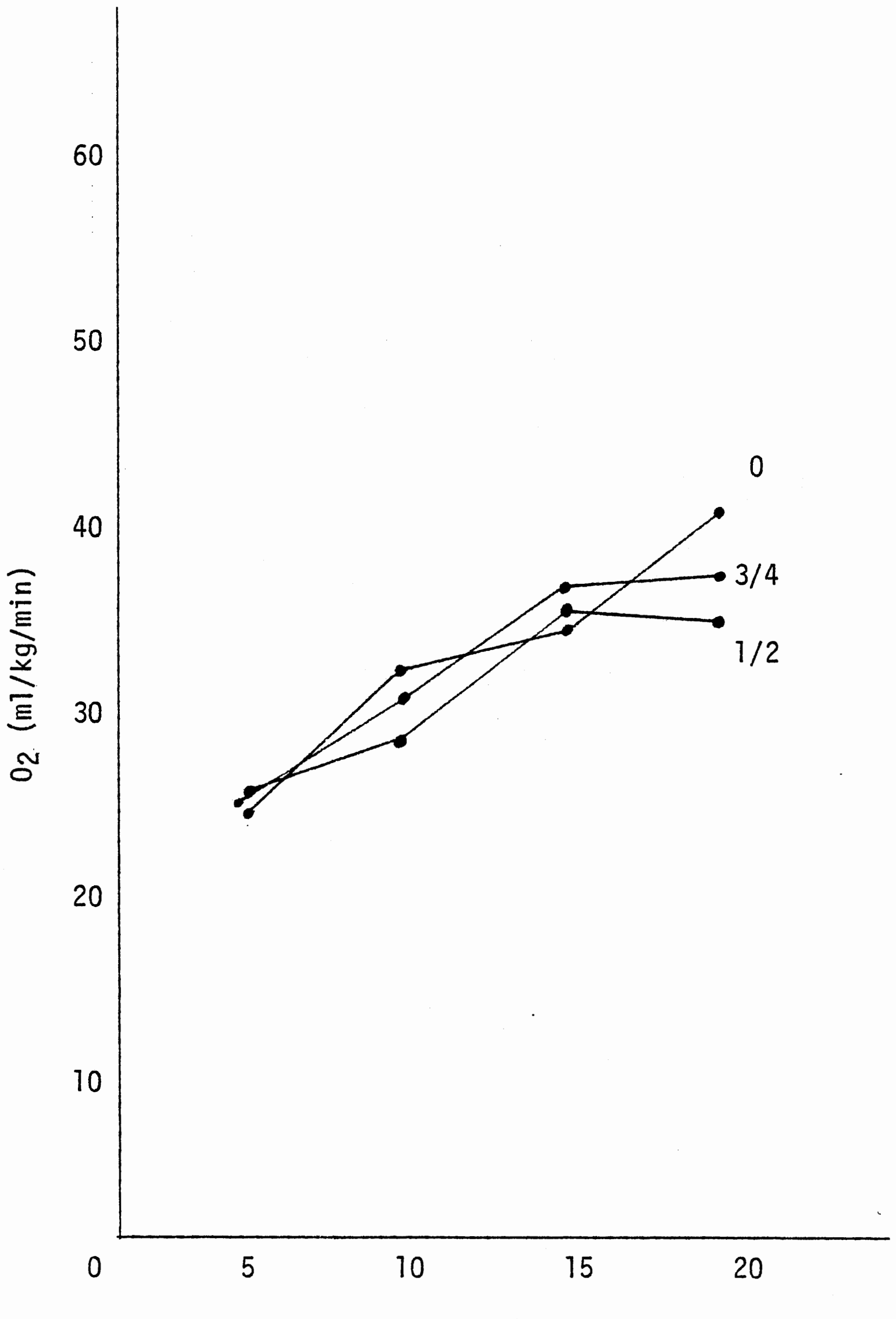

Figure 5. Oxygen Consumption of Subject #3 at Three Leg Length Variables

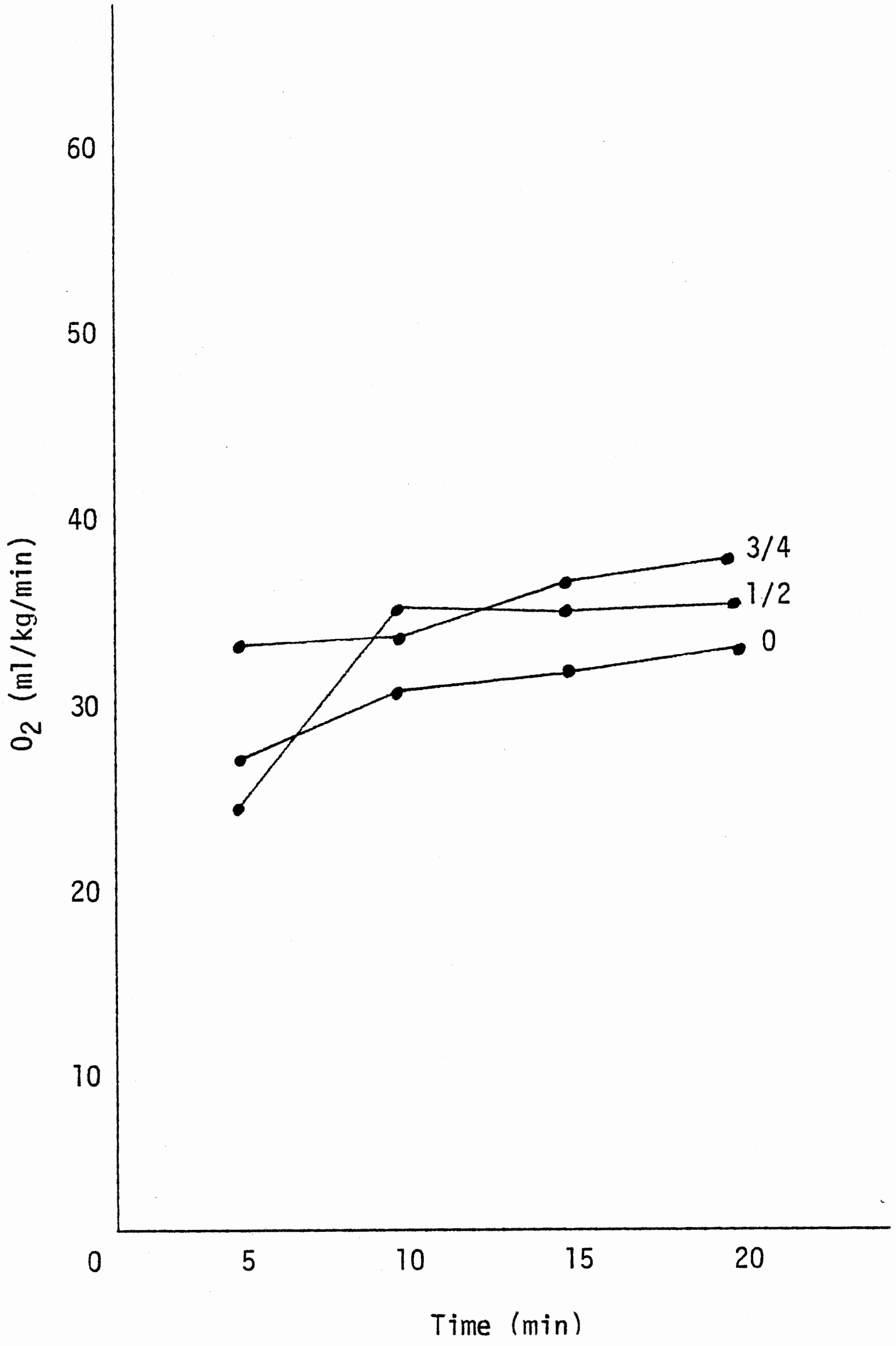

Figure 6. Oxygen Consumption of Subject #6 at Three Leg Length Variables

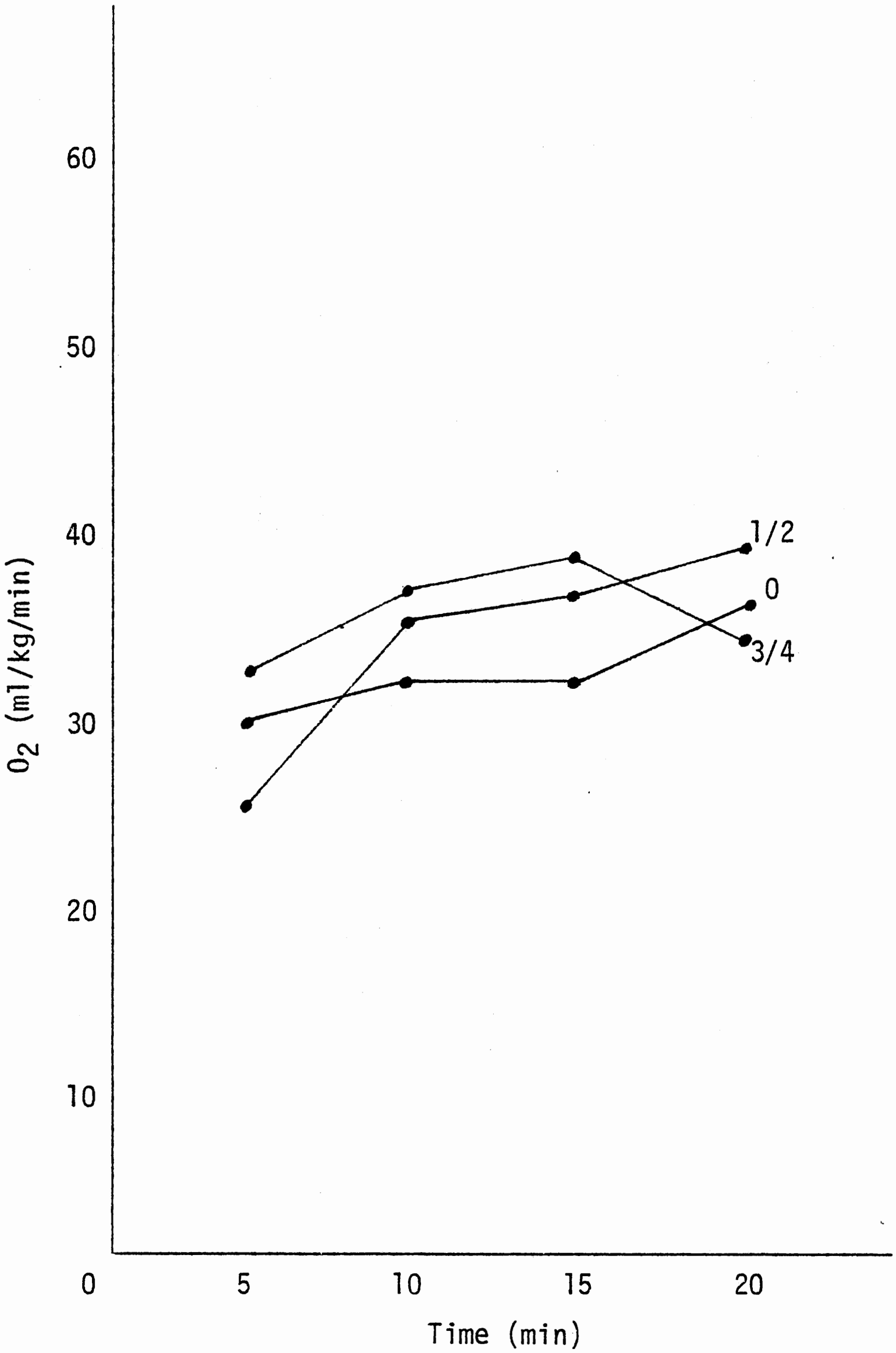

Figure 7. Oxygen Consumption of Subject #7 at Three Leg Length Variables

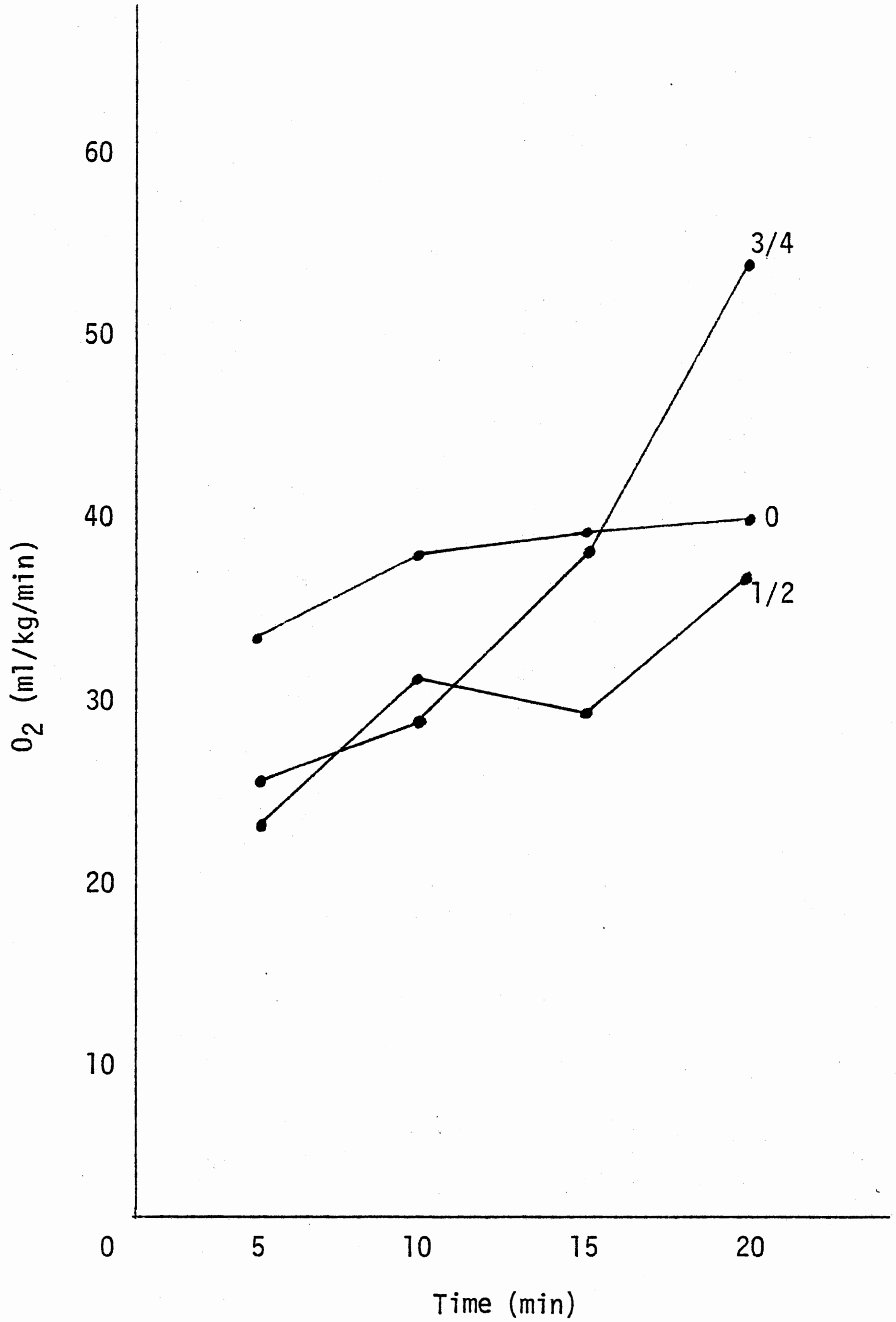

Figure 8. Oxygen Consumption of Subject #1 at Three Leg Length Variables

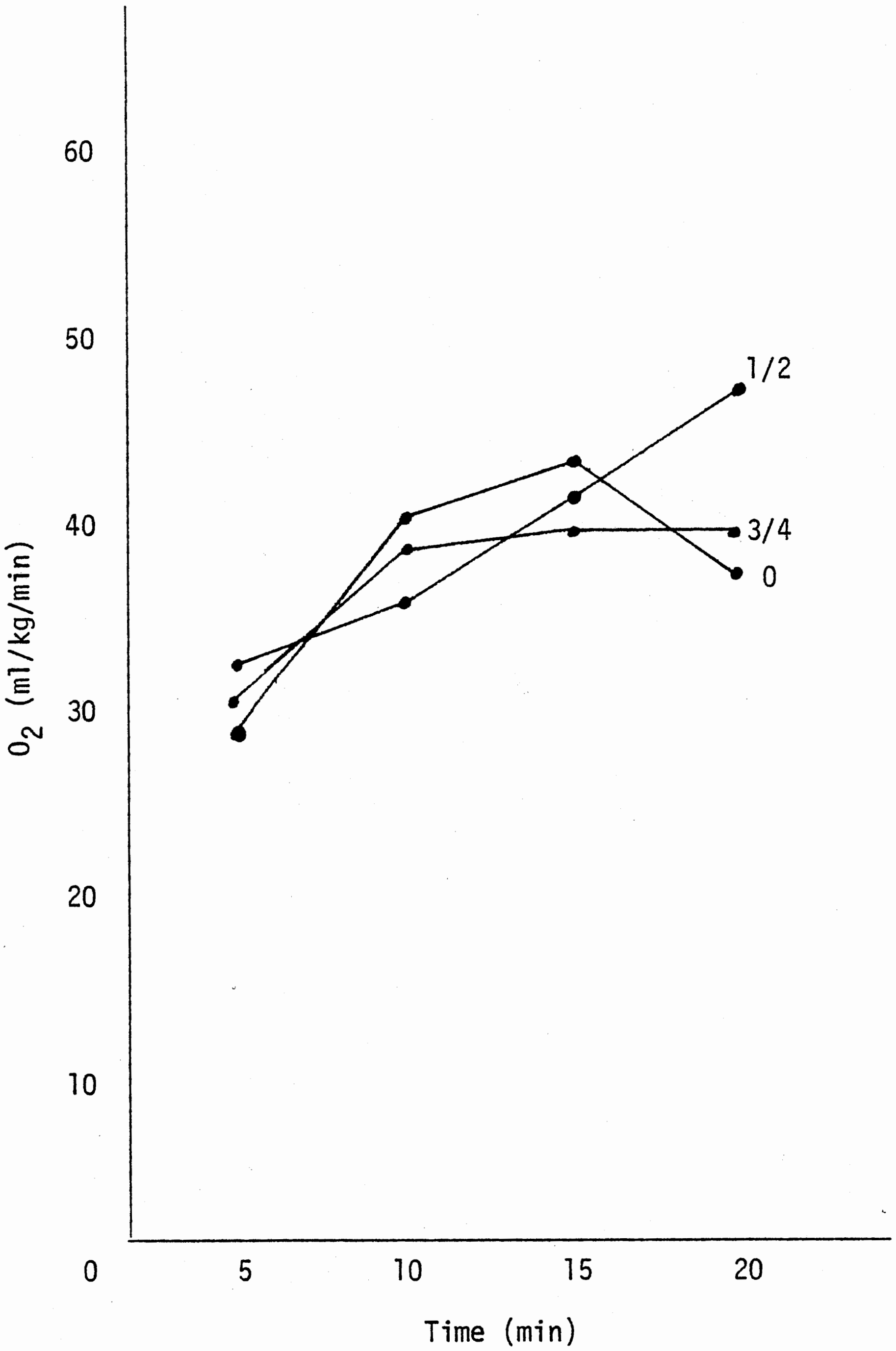

Figure 9. Oxygen Consumption of Subject #10 at Three Leg Length Variables

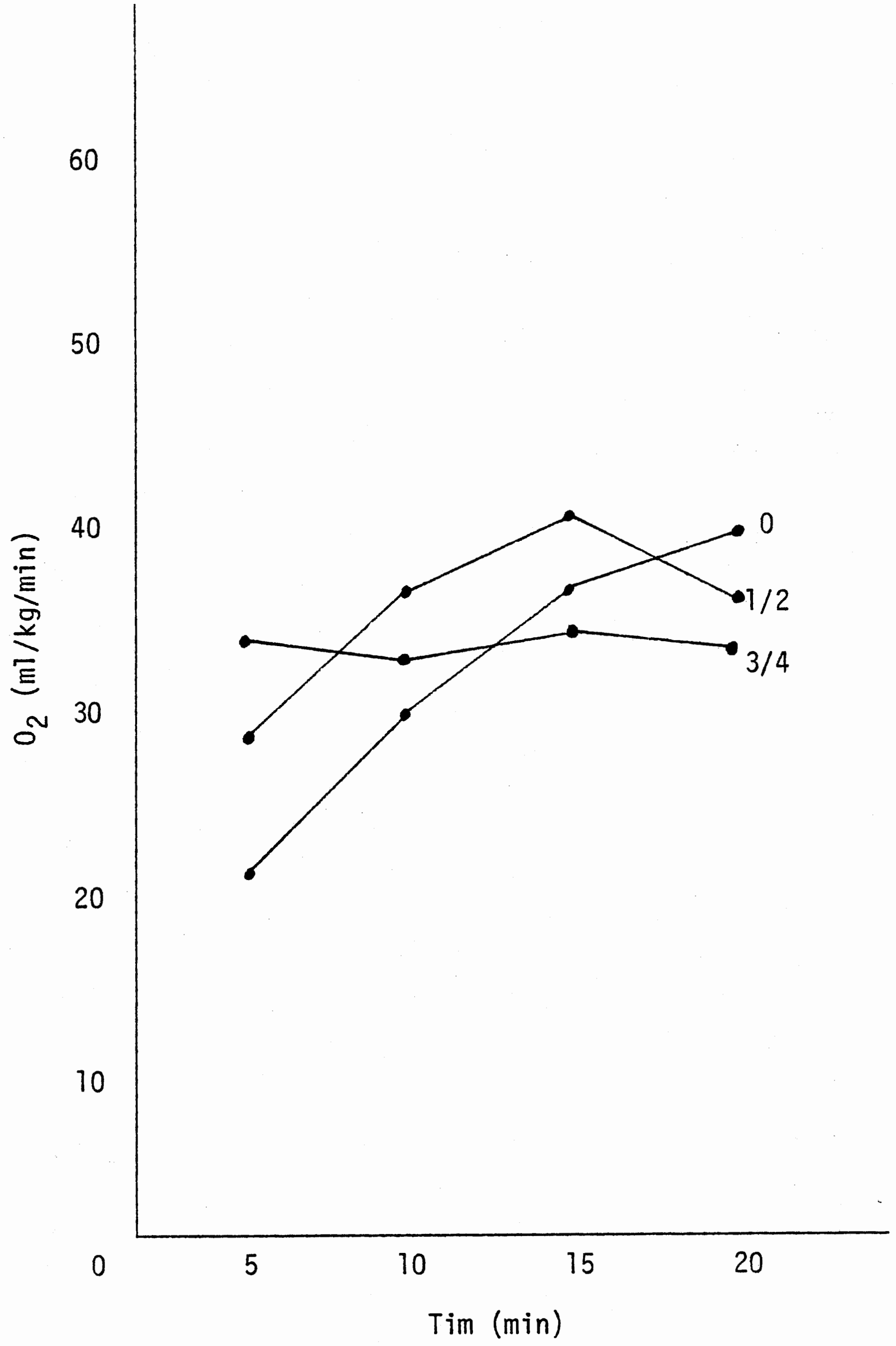

Figure 10. Oxygen Consumption of Subject #2 at Three Leg Length Variables

consumption on each of these three graphs occur at each of the three variables tested. Figure 5 shows the highest reading of 41.85 ml/kg/min to occur at the zero differential; Figure 6 depicts a high reading of 37.22 ml/kg/min, occurring at the three-fourths inch differential; while Figure 7 indicates that the high reading of 38.07 ml/kg/min occurred at the one-half inch differential.

The readings found in Figures 8-10 appear to be erratic and have no particular sequence or pattern to them. Several variables could have influenced the emergence of these three patterns of results. For example, since the cardiovascular level of the subjects was not taken into account, perhaps this was reflected in the findings. Other factors to be considered are the training effects which might have occurred, the amount of arm movement by the subjects, the lack or presence of motivation on the part of each individual, and human or mechanical errors in measurement. One or a combination of several of these factors could have influenced the patterns which are seen in Figures 1-10.

Due to the fact that only trends can be identified based on the results of the study, it would be difficult to make the assumption that the correction of minor leg length differentials would prove beneficial to the population as a whole. At submaximal exercise intensities, only slight increases in oxygen consumption could be found. Therefore, it is questionable as to what type of changes, if any, would occur in sedentary individuals. Based on this study, the correction of minor inequalities would not appear to be necessary, providing that there was no discomfort being experienced by the individual.

Differences Among Groups

At this point it would appear appropriate to examine the three groups of results as previously classified. Group A consists of the subjects in Figures 1-4; Group B consists of the results obtained in Figures 5-7; and Group C contains subjects depicted in Figures 8-10. Group A shows definite increases in oxygen consumption levels as leg length differentials increase. The average oxygen consumption for this group increased from the 5 minute time interval to the 20 minute time interval at each leg length differential from zero to three-quarters inch. The lowest oxygen consumption reading of 30.58 ml/kg/min was obtained at the 5 minute, zero differential, and the high reading of 52.42 ml/kg/min occurred at the 20 minute, three-quarter inch differential.

Group B showed results which were not as well defined as those of Group A. For each variable tested, the oxygen uptake increased as the time interval increased; however, there was not the consistency in oxygen increase and amount of leg length differential. The lowest reading for this group occurred at the five minute, one-half inch reading (25.63 ml/kg/min); the highest reading of 38.00 ml/kg/min came at the 20 minute, zero differential reading. The three subjects in Group C exhibited somewhat erratic results. As in Group B, the oxygen consumption does increase with time, but it does not appear to be in any type of relationship with the leg length differential. The reading of 27.55 ml/kg/min was the lowest for this group and occurred at the five minute, one-half inch differential mark. The highest reading of 41.66 ml/kg/min occurred at the 20 minute, three-quarter inch differential. These results are shown in Figures 11-13.

The average oxygen consumption for each group was figured for the zero differential, 20 minute time interval. Since this reading would more closely approximate the values obtained in a maximal oxygen consumption test, they were used to estimate the fitness classification of each group. Fitness levels were determined by norms based on maximal oxygen consumption values. Group A showed an average oxygen intake value of 36.59 ml/kg/min; Group B, an average of 38.00 ml/kg/min; and Group C, an average reading of 39.65 ml/kg/min. According to norms based on maximal oxygen consumption values, each of these readings would fall into the average category (34-41 ml/kg/min). Group A, however, would be considered to be in somewhat better condition in that this submaximal test was being performed at a lower energy expenditure. Therefore, Group A would have to continue the exercise for a longer period of time than either Group B or C to reach maximum values (49+ml/kg/min). The latter two groups are working at higher energy levels and are approaching maximum values at a faster rate. It would seem that Group A is the more highly conditioned of the three groups. A training effect when it occurs has a greater bearing on individuals at lower fitness levels than it does on more highly conditioned subjects. Since this is true, the results of the subjects in Group A could be due to the leg length variable and not hidden by the negligible training effect which might have been occurring. Conversely, in Groups B and C, the training or conditioning effect is having a much greater influence and in reality could be concealing differences which might otherwise be attributed to the leg

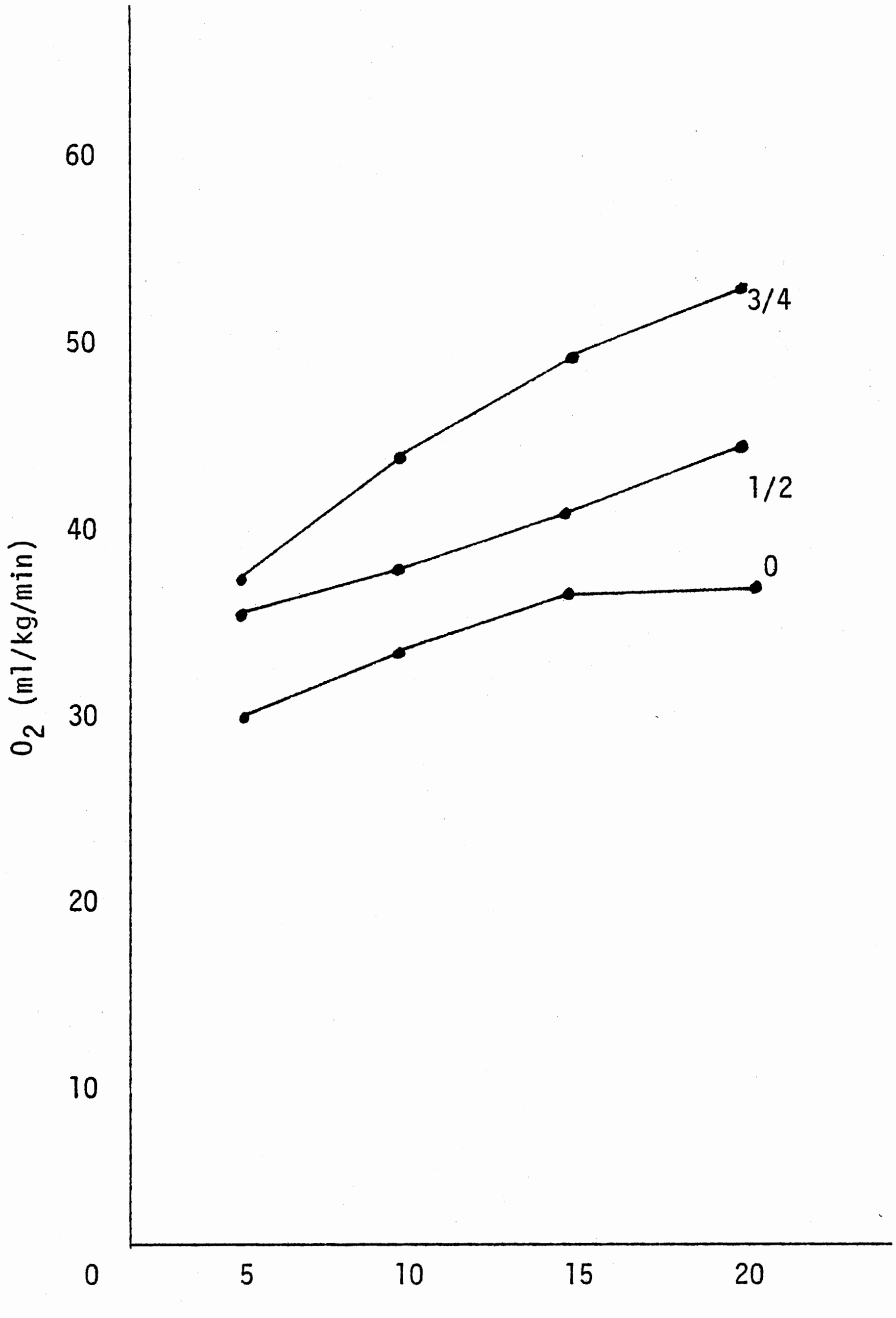

Figure 11. Group A Average Oxygen Consumption at Each Variable Tested

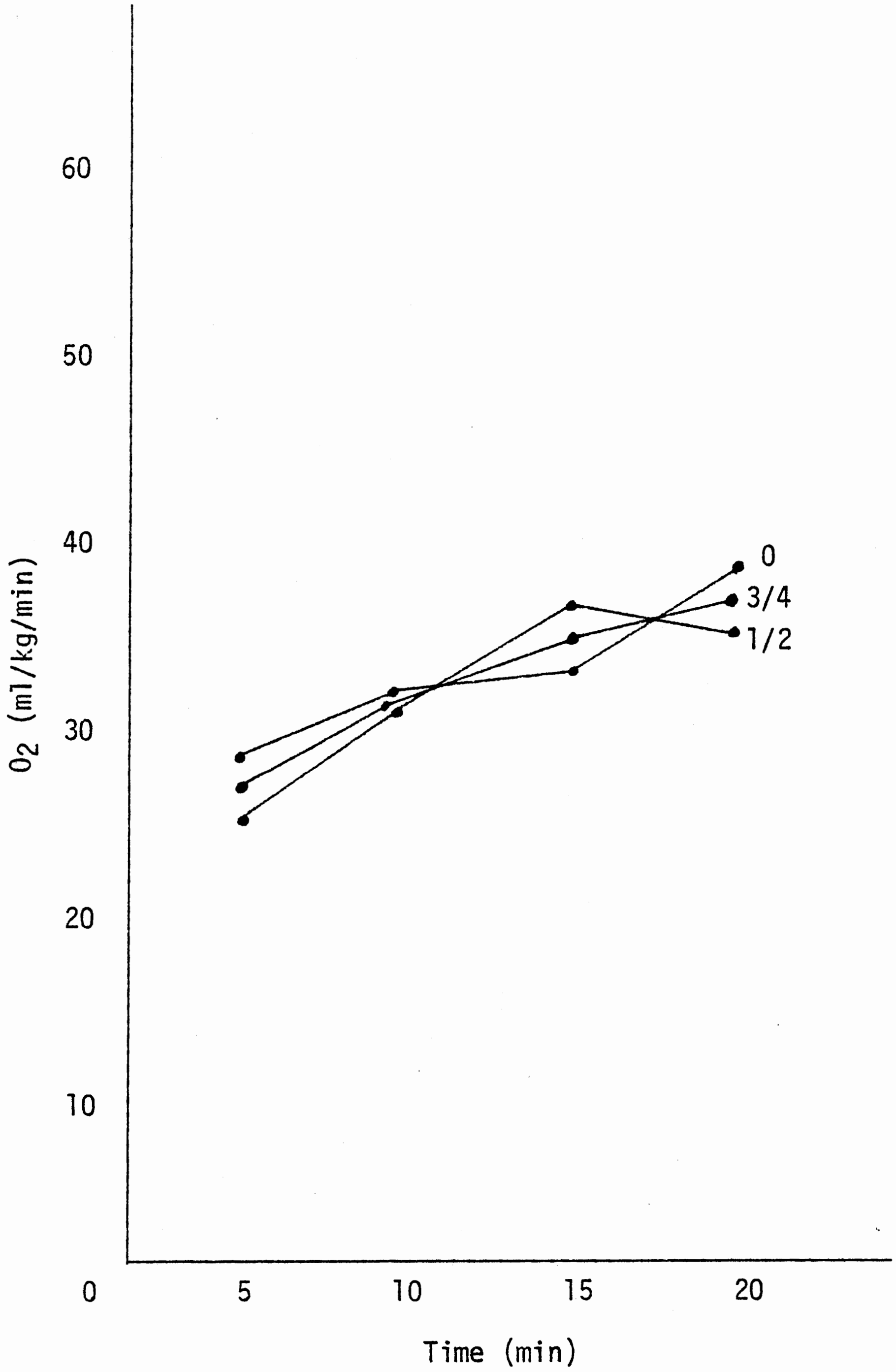

Figure 12. Group B Average Oxygen Consumption at Each Variable Tested

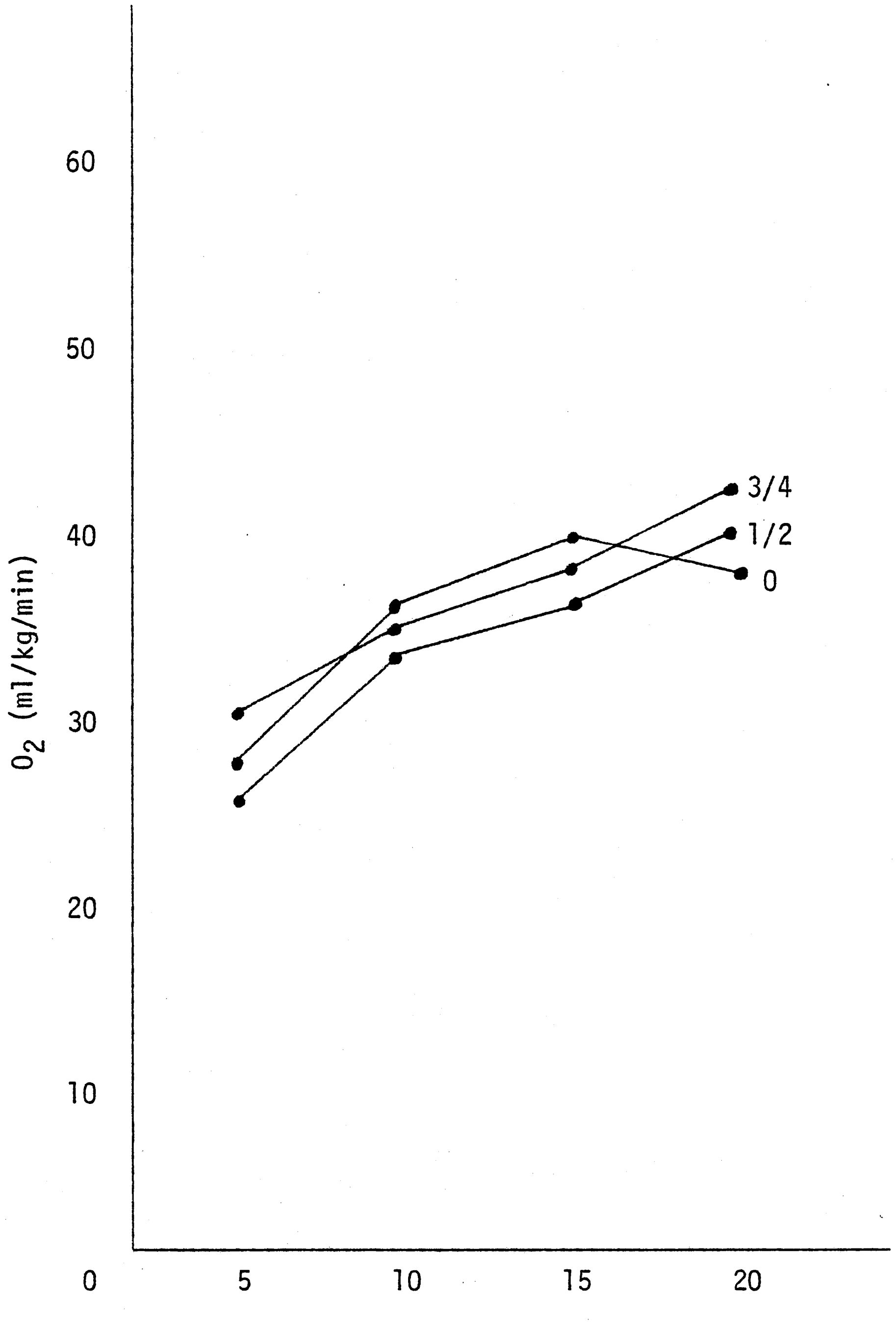

Figure 13. Group C Average Oxygen Consumption at Each of Three Variables

length differential. This fact might well have accounted for the unexplained results of Groups B and C. It would appear from this study that training and conditioning must be taken into account before definite conclusions can be drawn.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

For many years much of the work done in the area of leg length differential was related to traumatic or disease deformities that resulted in noticeable variations in length. The studies conducted showed that energy expenditure did increase as a result of the differential; therefore, ambulation was more difficult and utilized more oxygen as a result of leg length inequalities.

It was the purpose of this study to determine the effect of minor leg length differences on ambulatory oxygen consumption levels. Specifically investigated were differentials of zero, one-half, and three-fourths inch. A constant speed of three miles per hour and a constant grade of 16% were utilized for the submaximal exercise tests.

Conclusions

Within the limits of this study and based on the null hypotheses stated, the following conclusions were made:

1. There will be no significant difference in oxygen consumption levels between a one-half inch differential in leg length and zero differential as measured at 5, 10, 15, and 20 minute time intervals. This hypothesis was accepted. The F ratios obtained from a Single Way ANOVA - Repeated Measures Design were not significant at any of the four time intervals.

2. There will be no significant difference in oxygen consumption levels between a three-fourths inch differential in leg length and zero differential as measured at 5, 10, 15, and 20 minute time intervals. This hypothesis was accepted. The F ratios obtained from a Single Way ANOVA - Repeated Measures Design were not significant at any of the four time intervals.

3. There will be no significant difference in oxygen consumption levels between a one-half inch leg length differential and a three-fourths inch differential as measured at 5, 10, 15, and 20 minute time intervals. This hypothesis was accepted. The F ratios obtained from a Single Way ANOVA - Repeated Measures Design were not significant at any of the four time intervals.

Recommendations

One of the greatest deterrents to this study was the fact that the training effect was not accounted for through the use of a pre and post maximal oxygen consumption test. If it could be determined that conditioning did not occur, then the results obtained could be attributed to the leg length variable and not hidden by changes in oxygen consumption brought about by conditioning. Another advantage of using the maximal oxygen consumption tests would be to allow an assessment of the subject's present level of cardiovascular fitness based on treadmill time. This knowledge might allow conclusions to be drawn regarding relationships between fitness levels and the effect of the leg length variables. It might be found that individuals in the higher fitness categories are either more or less affected by this variable than those in lower fitness classifications.

A larger population might also have been helpful in this study. If the training effect can be controlled, it is assumed that a larger number of subjects might yield more statistically significant results. In the present study, 4 of the 10 subjects did show definite increases in oxygen consumption as the leg length differential increased. Therefore, with a larger population and control of the training effect variables, the results might appear differently.

It might have been useful to allow the subject to walk with the heel lift in place for a period of time prior to the actual testing. Some of the subjects in this study complained of minor discomfort which might have been eliminated with some practice time.

Other suggestions would include a closer control of the subject's exercise and dietary patterns prior to the testing and the use of a third person in the collection and accumulation of data during the actual testing.

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APPENDIX

SUBJECT CONSENT FORM

I have been told that Oklahoma State University, like virtually all other universities in the United States, does not have a mechanism for compensation of the injured research subject; therefore, I understand that I cannot look to any such mechanisms to receive financial remuneration for any such injuries resulting from my participation in this research project.

I understand that the data collected here will be used for scientific research and will receive only impersonal statistical treatment with my right of privacy protected. None of my data will be revealed in individualized form to another person without my prior written consent. Further, I recognize that I can discontinue participation in this research study at any time without penalty of any kind.

I have been given adequate opportunity to ask questions, and any questions which have occurred to me concerning this project or this informed consent have been answered to my satisfaction.

In recognition and understanding of the above, I hereby freely consent to participate as a research subject.

________________________________ Date________________________

Signature of Research Subject Mo. Day Year

________________________________ Date________________________

Signature of Witness Mo. Day Year

Lab Information Sheet

SUBJECT__________________ DATE__________ AGE______ HT______ WT______

TEMP______________ degrees BAROMETRIC PRESSURE__________ mm Hg Corr______

Resting (2 min ventilation) Leg Differential ____________________ H.R.________

1\. Oxygen %____________ CO2%______________ True O2____________

2\. Ventilation/min = $\frac{\_\_\_\_\_\_\_\_}{10}$ kym mm = __________ x1.332 = __________ L/min.

3\. Corr. vent = Vent. x Corr Factor = ____________ x ____________ = L/min.

4\. O2 intake = $\frac{\text{Corr vent x True O2}}{100}$ = $\frac{X}{100}$ = L/min.________________

5\. O2 intake = $\frac{\text{L.O2 x 1000}}{\text{wt/kg}}$ = ______________________

••

5 min 30 second H.R.__________

1\. Oxygen %________________ CO2 %____________ True CO2__________

2\. Ventilation/min = $\frac{\_\_\_\_\_\_\_\_}{10}$ kym mm = ___________ x1.332 = ______ L/min.

3\. Corr. vent = Vent. x Corr Factor = _______________ x ____________ = L/min.

4\. O2 intake = $\frac{\text{Corr vent x True O2}}{100}$ = $\frac{X}{100}$ = L/min. __________________

5\. O2 intake = $\frac{\text{L.O2 x 1000}}{\text{wt/kg}}$ = __________________________

••

10 min 30 second H.R.__________

1\. Oxygen %______________ CO2%________________ True O2__________

2\. Ventilation/min = $\frac{\_\_\_\_\_\_\_\_}{10}$ kym mm = __________ x1.332 = __________ L/min.

3\. Corr. vent = Vent. x Corr Factor = ______________ x ____________ = L/min.

4\. O2 intake = $\frac{\text{Corr vent x True O2}}{100}$ = $\frac{X}{100}$ = L/min.____________________

5\. O2 intake = $\frac{\text{L.O2 x 1000}}{\text{wt/kg}}$ = __________________________

••

15 min 30 second H.R.____________

1. Oxygen %____________ CO2%____________ True O2____________

2. Ventilation/min = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ kym mm = ____________ x1.332 = ____________L/min

3. Corr. vent = Vent. x Corr Factor = ____________ x ____________ = L/min.

4. O2 intake = $\frac{\text{Corr vent x True O2}}{100} = \frac{X}{100}$ = L/min.____________

5. O2 intake = $\frac{\text{L/M x 1000}}{\text{wt/kg}}$ = ____________

* * *

20 min 30 second H.R.____________

1. Oxygen %____________ CO2%____________ True O2____________

2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ kym mm = ____________ x1.332 = ____________L/min.

3. Corr. vent = Vent. x Corr Factor = ____________ x ____________ = L/min.

4. O2 intake = $\frac{\text{Corr vent x True O2}}{100} = \frac{X}{100}$ = L/min.____________

5. O2 intake = $\frac{\text{L/M x 1000}}{\text{wt/kg}}$ = ____________

2

VITA

Marcia Ray Burrus

Candidate for the Degree of

Doctor of Education

Thesis: THE EFFECT OF LEG LENGTH DIFFERENTIAL ON AMBULATORY OXYGEN CONSUMPTION

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Minor Field: Health, Physical Education, and Recreation

Biographical:

Personal Data: Born in Texarkana, Arkansas, January 30, 1945, the daughter of Mr. and Mrs. Lynn W. Burrus.

Education: Attended elementary and junior high school in Oklahoma City, Oklahoma; graduated from Edison High School, Tulsa, Oklahoma, in 1963; received Bachelor of Science degree from Tulsa University in January, 1968; received Master of Science degree from Oklahoma State University in May, 1969; completed requirements for Doctor of Education degree at Oklahoma State University in December, 1983.

Professional Experience: Taught physical education in Tulsa Public Schools from January, 1968-May, 1969; taught physical education at the University of Arkansas, Fayetteville, Arkansas, from 1969-71; joined faculty of Tulsa University, Tulsa, Oklahoma, in September, 1971, presently serving as Assistant Professor of HPER.

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