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THE CONTRIBUTION OF INCREASED AEROBIC CAPACITY AND STRIDE LENGTH ALTERATION TO INCREASED PHYSICAL WORK CAPACITY

A Thesis

by

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STRIDE LENGTH ALTERATION TO INCREASED
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ABSTRACT

THE CONTRIBUTION OF INCREASED AEROBIC CAPACITY AND
STRIDE LENGTH ALTERATION TO INCREASED
PHYSICAL WORK CAPACITY. (1985)

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The purposes of this study were (1) to examine the contribution of physiological adaptation versus stride length adaptation to increased physical work capacity after an 11 week aerobic training program for beginning runners and (2) to determine if males and females responded differently to the variables tested.

The study utilized 21 beginning runners, 10 males and 11 females. The subjects were pre and post tested using the Bruce Graded Exercise Test to determine physical work capacity and a treadmill test at zero percent grade to determine stride length at 65% of the subject's maximum oxygen uptake. After pre-testing the subjects participated in an 11 week aerobic training program training within a prescribed heart rate range, 3 days per week, 20-40 minutes per session.

Pre and post data were collected on physical work capacity, maximum oxygen uptake, and stride length at a speed which represented 65% of the original maximum oxygen uptake. The data were analyzed using the Analysis of Variance (ANOVA) with repeated measures. A 2 x 2 factorial ANOVA was used to analyze the homogeneously grouped data. The alpha level of .05 was utilized to determine significance.

The training program produced a significant increase in physical work capacity in both males and females. Significant gains were not found in maximum oxygen uptake in the heterogeneous or homogeneous data groups. Stride length changes for the group were not significant. However, significant interaction was noted when the data were homogeneously grouped. The female subjects shortened their strides while males lengthened their strides during the 11 weeks of training.

The study suggests the $\dot{V}O_2$ was not the major factor for increased physical work capacity. It did suggest that stride length could have been a major contributing factor to improved performance. The study was unable to quantitatively define the precise contribution of either variable to improved performance.

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Chapter 1

Introduction

In the last 2 decades running has experienced increased popularity as the general population has become more aware of the importance of fitness. Running has been recognized as the most efficient method of developing cardiovascular fitness and has been widely used by the general population as a convenient method of exercise (James, 1973). However, since most running experts and coaches believe that each runner will develop his own most efficient style very little attention has been given to the biomechanics of running (Nelson and Gregor, 1976). Yet, Cavagna (1978) demonstrated that the mechanical efficiency of running was very low, suggesting that with training and practice increased mechanical efficiency in terrestrial locomotion could be achieved. Studies of trained runners have indicated that those runners with a greater ability to use oxygen also had better performances. These same studies concluded that some other factor must determine success in competition as some runners with significantly different oxygen uptakes had similar performances and those with equal oxygen uptakes had widely varying performances (Cavanaugh, Pollack, & Landa, 1977; Costill, 1979; Miyashita, Miura, Kobayashi, & Hoshikawa, 1973). After comparing the biomechanics of experienced runners, Cavanaugh, Pollack and Landa (1977) concluded that the basic question still remained as to whether efficient running was the result of good mechanics, the cellular ability to utilize oxygen or some weighting of both.

No studies have been found which attempt to determine the relative contribution of running mechanics and aerobic capacity to improved performance in either trained or untrained runners. The question of determining the relative importance of mechanics and aerobic training to improve running performance needs to be examined and clarified.

Statement of Problem

Some research has been devoted to the contribution of biomechanics to running economy in trained runners as well as the differences demonstrated between trained and untrained runners (Cavanaugh, Pollack, & Landa, 1977; Hubbard, 1937; Hoshikawa, Matsui, & Miyashita, 1973). There was no available research which dealt specifically with the improvement in physical work capacity as related to increased aerobic capacity or altering of mechanics in beginning runners engaged in a running program. The present study explored the factors responsible for increased work capacity as related to increased maximum oxygen uptake and stride length alterations.

Studies Related to Oxygen Uptake and Performance

Maximal oxygen uptake has long been used as a method of determining physical work capacity also known as performance. Astrand and Saltin (1961) developed the use of maximal oxygen uptake as the best physiological indicator of the aerobic work capacity of man. Several studies have noted higher maximal oxygen uptakes in trained runners and subsequently better performances by these more highly trained individuals (Bransford & Howley, 1977; Hubbard, 1937; Miyashita, Kitaqmura, Yamada and Matsui, 1978; Miyamura, 1978; Miyashita, 1973).

Hollozsy, Rennie, Hickson, Conlee and Hagbert (1977) noted the most important adaptive response of muscle to exercise was increased respiratory capacity to use available substrates for energy. The muscles' increased capacity for respiration was a direct result of increased mitochondrial concentration due to endurance training. Cardiovascular adaptations which occur with training included higher cardiac output and greater stroke volume. These factors contributed to greater oxygen consumption and improved performances (Holloszy, et al., 1977; Miyamura, et al., 1978).

While the ability to consume, transport and utilize oxygen in volume was noted by Costill, in 1979, as being a critical factor in endurance running, it did not necessarily predict winning performances. Runners possessing very different maximal oxygen uptakes had very similar performances in competition. Miyashita and others (1973) also noted the trend was for performers with higher maximal aerobic capacities to have better performances. However, individuals with the same oxygen uptakes demonstrated a .46 meters per second difference in performance during a 5,000 meter race. Hubbard (1937) noting the research of others, suggested that while training would make some difference in general metabolic ability to utilize oxygen, that factor alone could not account for the difference in performances of trained and untrained subjects.

In determining the maximal oxygen uptake values of subjects the aspect of training specificity must be considered as demonstrated in studies by both Miyamura, et al. (1978) and Verstappen, Huppertz and Snoecky (1982). Those subjects who had trained by running had significantly different maximal oxygen uptake values when tested on a treadmill and again on a bicycle ergometer. As expected the cyclists performed with higher maximum oxygen uptakes on the cycle ergometer test when compared to the treadmill test. These two studies demonstrated the need for task specificity in conducting maximal oxygen uptake evaluations.

Stride Length and Oxygen Consumption

In 1982, Cavanaugh and Williams studied the effects of varied stride lengths on oxygen consumption in long distance runners. The runners were tested using seven different stride lengths at the same speed. Subjects used the freely chosen stride length and then six stride lengths which were greater and less than the chosen stride length by 6.7, 13.4 and 20.0%. The study demonstrated a low correlation between oxygen uptake at an optimal calculated stride length and actual stride length as a function of leg length. Optimal stride length was calculated as that stride length requiring the lowest oxygen uptake as determined by a regression equation. The oxygen uptake difference between the freely chosen stride length and the optimal stride length was 0.2 ml/kg x min^{-1}.

The mean absolute difference was 4.2 centimeters. The researchers concluded that small changes in stride length had no major effect on oxygen consumption. Cavanaugh concluded that trained runners run at a stride length and stride frequency which is close to optimal either by a conscious or unconscious adaptation. The runners made the adaptation based on physiologically perceived exertion or has adapted to a number of stride length, stride frequency combinations which fit the style of running which was required (Cavanaugh & Williams, 1982).

Powers, Hopkins and Ragsdale (1982) studied the oxygen uptake in experienced female runners at stride lengths which varied +- 15% from the freely chosen stride length. Subjects were tested at between 60 and 80% of the maximal oxygen uptake determined during the freely chosen stride length measures. Treadmill speed was maintained throughout the tests. Oxygen uptake was significantly lower in the tests using freely chosen stride length while no significant difference was noted in oxygen uptake between the shorter and longer stride lengths. The researchers noted that the results were similar to those found in men.

In 1961, Knuttgen studied two factors involved in energy cost of level treadmill running, kinetic energy and the subjects' stride length adaptations to speeds using undetermined and pre-determined stride lengths. The study showed a rectilinear relationship between velocity squared and oxygen uptake up to 14 kilometers per hour (km/h) and a linear relationship between 9.66 and 11.66 km/h using undetermined stride lengths (self-selected). The energy cost of pre-determined stride lengths which were shorter than the undetermined stride length showed little or no variation from the undetermined stride length energy costs. Energy expenditure increases were noted with larger deviations from the freely chosen stride length. Increases in stride length were directly related to increases in running speed using undetermined stride lengths (Knuttgen, 1961). Hogberg (1952) was one of the first to study the effect of varied stride lengths and stride rates on oxygen utilization. A single subject was tested and demonstrated that the most economical stride length lies very close to the freely chosen stride length. The study also noted that at every speed an optimal stride length and stride rate exist for individual runners.

In 1973, van der Walt and Wyndham conducted a study to determine which factors could be used in an equation to determine energy expenditure in locomotion. Six untrained males were tested at walking and running speeds on a level treadmill. The study showed that oxygen uptake at any speed was directly related to body mass during walking. Further, stride length and leg length could not be shown to have a significant influence on energy cost of walking. In running, differences in stride length and leg length accounted for only 2% of the variance in oxygen uptake.

Running Mechanics Trained Versus Untrained

While running appears to be an inherent skill, researchers have repeatedly noted that running as a skill is not merely a faster walk, but rather a learned skill requiring adaptations in lengthening stride (Hubbard, 1937; James & Brubaker, 1973).

Furthermore, James and Brubaker (1973) reported the basic gait for running was established by physical and developmental determinants. To alter a habitual motor pattern great conscious effort must be exerted and the increased concentration factor required to affect change may prove to be very disadvantageous. The researchers suggested that with training and practice successful competition resulted even if the ideal physical characteristics for running were not possessed by an individual. In some cases even with training and adaptations in overall mechanics the increase in mechanical efficiency would not be sufficient to allow the individual to be highly competitive.

Cavanaugh, Pollack and Landa (1977) studied the biomechanical differences in elite and good distance runners. The variables measured were stride length, stride rate and lower limb kinematics. The two groups were significantly different in oxygen uptake which was possibly due to a difference in biomechanics. Twenty-two runners were tested on a level treadmill. Only minor differences between groups were noted with the good runners using slightly longer stride lengths with concommitant changes in associated variables. Good runners were also more assymetrical in vertical displacement than the elite runners. Most importantly the elite runners used stride lengths which were closely related to their leg lengths (r=.67) while the good runners had a low correlation (r=-.10) between stride lengths and trochanterion height.

Hoshikawa, Matsui, and Miyashita, in 1973, analyzed the running patterns of 8 males in relation to speed of the treadmill.

The running experience ranged from Olympic caliber to non-runners. Analysis of running patterns at different speeds demonstrated that at the lower speeds running velocity was largely a product of stride length adaptations while at the higher speeds stride rate was the key factor in running velocity. Goniogram data of the movement patterns indicated a significant difference between the excellent runner and the poor runners at both the highest and lowest speeds.

Nelson and Osterhoudt studied the effects of altered slope and speed on running mechanics in a 1971 study. Three speeds and slopes were compared in 16 experienced runners. A sloped platform was used for the testing to obtain a 10% incline and decline along with a zero percent incline. Significant differences among individuals were noted in stride length analysis at all speeds and all slopes. Increases in speed were coupled with increases in stride length as well as stride rate. Stride length was also effected by slope with downhill running producing the longest stride and uphill running the shortest stride length (Nelson & Osterhoudt, 1971).

In 1979, Elliott and Blanksby studied optimal stride length considerations in recreational runners, both males and females. Freely chosen stride length, stride rate and changes at four graded velocities were studied in the experienced runners. The data demonstrated a linear relationship between stride length and stride rate with increasing velocity from 2.5 meters per second (m/s) to 5.5 m/s in both genders. Significant correlation values in stride length to leg length values were found in the female subjects at all speeds tested while significant correlation values were found in the males at speeds of 3.5 m/s and higher. A significant relationship between stride length and total body height existed in males at speeds of 4.5 m/s and 5.5 m/s and at all speeds in the female subjects. The results indicated that leg length and total height may be important factors in determining an optimal stride length for distance runners.

The biomechanical changes experienced over time by distance runners were examined by Nelson and Gregor in 1976. The researchers noted a dearth of information concerning the change in mechanics in runners over time. Nelson and Gregor studied five components of running: stride length, stride rate and stride time divided into support and non-support phases. The longitudinal study involved distance runners at the college level. The study established the fact that experienced runners change mechanics over time to a more efficient style as manifested in faster performances. The statistical analysis revealed significantly different values in all components over the 4 year study. Stride lengths decreased as did time of support with a concommitant increase in stride rate (Nelson & Gregor, 1976).

Overground Running Versus Treadmill

The question of whether data collected using the treadmill can be generalized to overground locomotive activity has been a long-standing controversy. In 1960 Ralston compared energy expenditure of floor walking to treadmill walking. Previous studies had noted a significant difference in energy expenditure which Ralston demonstrated to be insignificant once light, rubber-soled shoes and walking surfaces were considered when comparing the exercises.

Nelson, Dillman, LaGasse, and Bickette (1972) compared the biomechanics of running on a treadmill to that of overground running. Stride length was significantly different only at 6.4 m/s in both the horizontal and uphill runs. On the treadmill, stride lengths at 6.4 m/s were 4.7% and 8.4% longer, respectively. Complete analysis of the temporal data resulted in only slight differences in stride length and stride rate between overground and treadmill runs. A significant difference was noted in the work done with treadmill work being less than that of overground running.

In a cinematographic study of mechanics Elliott and Blanksby (1976) studied 24 male and female experienced joggers comparing stride length and stride rate and two other temporal variables of overground to treadmill running. Statistical analysis showed no significant difference in stride length or stride rate at 4.8 m/s, but at speeds greater than 4.8 m/s a significant difference was noted. Stride length was shorter by 3.2% and 10.2% in females and males respectively, on treadmill runs of greater than 4.8 m/s.

Ingen Schenau (1980) examined some fundamental aspects which should be considered in analyzing running between stationary and moving surfaces. By utilizing the appropriate coordinate system in analyzing movement, differences in overground and treadmill running were shown by theoretical example to be insignificant. In treadmill running a reference frame which moves with the belt is needed to calculate mechanical variables. Previous studies had used a stationary frame. Ingen Schenau also stated that to insure greatest similarity between overground and treadmill running the treadmill motor must be strong enough to maintain a constant velocity at maximal load and the belt should not be influenced by the perpendicular force of the runner. The researchers stated that if all of these factors could be controlled, the only significant difference between overground and treadmill running would be air resistance.

Null Hypothesis

The following null hypotheses were tested in this study:

1. There was no difference in physical work capacity as measured by time spent on the Bruce Graded Exercise Test (BGET).

2. There was no difference between pre and post test values in maximal oxygen uptake after 11 weeks of training.

3. There was no difference in the stride length at the same speed which required 65% of the original $\dot{V}O_2$ max after 11 weeks of training.

4. There was no difference between the males and females in any of the variables tested.

Research Hypothesis

The following research hypotheses were tested during the study:

1. Maximal aerobic capacity would be greater at the end of 11 weeks as a result of 3 day per week training.

2. Physical work capacity would be greater after 11 weeks of training.

3. The subjects experienced an alteration in stride length at the same given speed after training for 11 weeks.

4. The greatest contribution to increased physical work capacity would be due to an alteration of stride length.

5. The contribution of increased aerobic capacity to increased physical work capacity, while significant, would be less than the contribution of biomechanical change expressed as stride length.

6. There would be a significant difference between the males and females in the variables tested.

Operational Definitions

Stride Length is the distance between successive heel contacts by opposite feet.

Beginning Runner is one who has never participated in athletics and has never run on a regular basis for more than a month at a time.

Physical Work Capacity (PWC) is the total amount of time performed on the treadmill utilizing the Bruce Graded Exercise Protocol.

Performance is used herein as the total time spent on the treadmill. Interchangeable with Physical Work Capacity.

Assumptions

During the study the following assumptions were made:

1. The subjects provided accurate information on the questionnaire used to define the subject population.

2. The subjects followed pre-testing instructions (Appendix A).

3. Each subject provided a maximal effort in all testing and used a freely-chosen stride length running in the individually normal style.

4. Each subject trained in the appropriate heart rate range during the 11 week training period.

5. The subjects did not participate in any other type of regular training during the study.

Delimitations

1. The subjects were 10 male and 11 female subjects from Appalachian State University enrolled in the Jogging/Conditioning activities courses.

2. The subjects were beginning runners as determined by a questionnaire completed by interested candidates.

3. The training program consisted of 3 days per week of endurance running for a total of 11 weeks.

4. Each subject was pre and post tested for PWC using the BGET.

5. Each subject was pre and post tested for stride length 48 hours after the BGET test.

Significance of the Study

The literature clearly indicates that physiological change in the body's ability to metabolize oxygen is an adaptation incurred due to regular aerobic exercise (Holloszy et al., 1977; Costill, 1979). Another study has indicated that biomechanical adaptations also occur with training and could possibly be a factor in improved performances when aerobic capacity has not increased (Nelson & Gregor, 1976). However, to date no studies have been conducted in an effort to quantify the contribution of physiological or biomechanical adaptation to improved performance in beginning runners. Therefore, the purpose of this study was to examine the contribution of physiological adaptations and biomechanical changes expressed as stride length to increased physical work capacity after an 11 week aerobic training program for beginning runners. A second purpose was to determine if males and females responded differently to the variables tested after 11 weeks of aerobic training.

CHAPTER 2

Methodology

Overview

The main purpose of this study was to determine the contribution of stride length adaptation versus physiological adaptation to improved performance. A second purpose was to determine if males and females experienced different adaptations to the same 11 week aerobic training program.

Subjects

The subjects for this study were beginning runners, 10 males and 11 females, enrolled in the jogging and conditioning classes at Appalachian State University. Beginning runners were selected so that both physiological and biomechanical adaptations to endurance running would be adequately demonstrated through the training program.

The initial meeting with the subjects consisted of subject completion of a questionnaire used to assist in the identification of beginning runners, a demonstration and explanation of the testing procedures and completion of a volunteer consent and release form. The questionnaire and consent form can be seen in Appendices B and C respectively.

Materials

All equipment used for testing was commercially produced and used professionally in the Human Performance Laboratory at Appalachian State University.

Subject height and weight was determined using a standard medical scale. Leg length was measured using a Gulick measuring tape.

In the testing for both maximal oxygen uptake and stride length evaluation a Quinton treadmill which had been adapted to measure stride was used. The Beckman MMI Metabolic Cart was used to analyze expired air for oxygen, carbon dioxide concentrations and determine $\dot{V}O_2$ workload. During both maximal and stride length tests subject heart rate was monitored using the Respironics Inc. Exersentry Heart Rate Monitor.

For the stride length determination tests, a Commodore Business Machines Model 4032 Microcomputer was used to collect data and calculate treadmill speed and stride length. A specially developed computer program (Harris, 1984) was used to calculate time between heel strikes, time for one belt revolution, and record subject anthropometric data and name. This information was used to provide stride length, stride length to leg length ratios, stride length to height ratios and treadmill speed computed to the nearest 0.01 of a second (see Appendix D). A mechanical microswitch attached to the treadmill and activated by the treadmill belt enabled the computerized calculation of belt speed during the test period. A switchmat was embedded in the treadmill platform and was used to detect heel strikes. The computer program was able to determine the time between heel strikes. In conjunction with the belt speed data this information was used to calculate stride length. A toggle switch permitted the operator to select the collection of either belt speed or stride length data.

Procedures

The first day of testing involved the subject being weighed, measured for total height and leg length from trochanterion to the floor in the running shoe (Plagenhoef, 1971). After initial values were taken the subject completed a maximal oxygen uptake test utilizing the Bruce Graded Exercise Protocol. During the test, gas samples were analyzed and stride length was monitored. Total treadmill time to completion was recorded as a measure of physical work capacity.

On the second day of testing each subject completed a level treadmill run at 65% of the maximal oxygen uptake test. Bransford and Howley, in 1977, concluded that recreational runners could tolerate exercise heart rates at 65% of their maximum $\dot{V}O_2$ without using the anaerobic energy system. During the level treadmill test stride length was assessed once a metabolic steady state had been established for 3-5 minutes. The speed of the run was noted for use on the fourth day of testing.

After the pre-tests had been completed the subjects engaged in a jogging and conditioning program for 11 weeks, three times per week and 20-40 minutes per session. During the training program no instruction in technique was offered and the subjects were allowed to train at a self-set pace within the training heart rate range established. The training heart rates ranged from 50-70% of the subject's maximal heart rate as established in the BGET. These controls were utilized to insure the changes which occurred would more closely parallel those experienced by the general population who run. The subjects used an indoor facility during inclement weather. During appropriate weather the subjects trained outside using either the outdoor track or the city sidewalks.

After 11 weeks of training each subject returned to the Human Performance Laboratory for a maximal aerobic capacity test using the BGET for post-test data. On the fourth and final day of testing the subject completed a stride length determination test at zero percent grade on the level treadmill at the same speed noted on the initial stride length determination test. This speed represented 65% of the subject's original aerobic capacity.

Procedures for Determining Maximal Oxygen Uptake

Maximal oxygen uptake was determined using the BGET (Appendix E). The BGET requires increases in speed and grade of the treadmill every 3 minutes until the subject can no longer endure the exercise. During the testing, oxygen uptake was monitored each minute by a Beckman Metabolic Cart. In the final minutes of exercise, gas analysis was done at 30 second intervals to assure that maximal oxygen values were recorded as accurately as possible. Criteria was established for maximal oxygen uptake when the oxygen uptake reached a plateau or decreased slightly with increased workloads (Astrand & Saltin, 1961). Total treadmill time was recorded as a measure of physical work capacity (performance). During the test the subject's heart rate was monitored by an Exersentry Heart Rate monitor (Appendix F).

Procedure for Stride Length Determination Test

In the stride length determination test each subject performed a warm-up run of 4 minutes to assure treadmill adaptation and to stabilize physiological variables. In the first stride length determination test the treadmill was maintained at zero percent grade and speed was increased until each subject reached 65% of the tested maximal aerobic capacity. After 5 minutes work at the metabolic steady state, the stride length was measured.

In the post-test stride length determination test each subject was tested at the same speed which originally required 65% of the subject's maximal aerobic capacity. The literature indicates the stride length increases linearly with increases in speed (Cavanaugh, Pollack, & Landa, 1977; Elliott & Blanksby, 1976, Elliott & Blanksby, 1979; Hogberg, 1937; Hoshikawa, Matsui, & Miyashita, 1973; Knuttgen, 1961; Nelson & Osterhoudt, 1971). Therefore, in order to analyze the mechanical adaptation in stride length as a result of training it was necessary to retest the subject at the original speed. The gas analysis equipment remained attached to the subject during stride length determination. See Appendix G for Stride Length Determination Data Sheet.

Procedure for Determining Time Between Heel Strikes

The methods used to determine stride length involved the utilization of a Commodore Model 4032 Microcomputer which had been interfaced with a switchmat embedded in the treadmill platform at a position which was the normal heel strike area. The switchmat interfaced the computer's internal timer circuit by way of the toggle switch and A to D converter and accessed via the computer user port. The computer program (Harris, 1984) calculated the time between heel strikes to the nearest 0.01 of a second. See Figure 1 for a diagram of the equipment used to determine stride length (Seymour, 1985).

Procedure for Determining Belt Speed of the Treadmill

For determining belt speed a microswitch was securely attached to the underside of the running board of the treadmill platform. This microswitch was triggered by a small leather strip which was glued to the treadmill belt. The leather strip closed the microswitch on each revolution. The microswitch was interfaced with the computer through the toggle switch which was attached to the microcomputer timer clock through the computer user port. Treadmill belt speed was determined by the computer program which divided treadmill belt length by the time between switch closures. Belt speed was provided in miles per hour.

Procedure for Determining Stride Length

In the stride length determination tests the stride length and belt speed were recorded when the desired steady state had been maintained for 3-5 minutes. The computer program was loaded into the computer and the subject's name, height and leg length were entered. The computer operator could then request a belt speed determination by setting the toggle switch to the appropriate

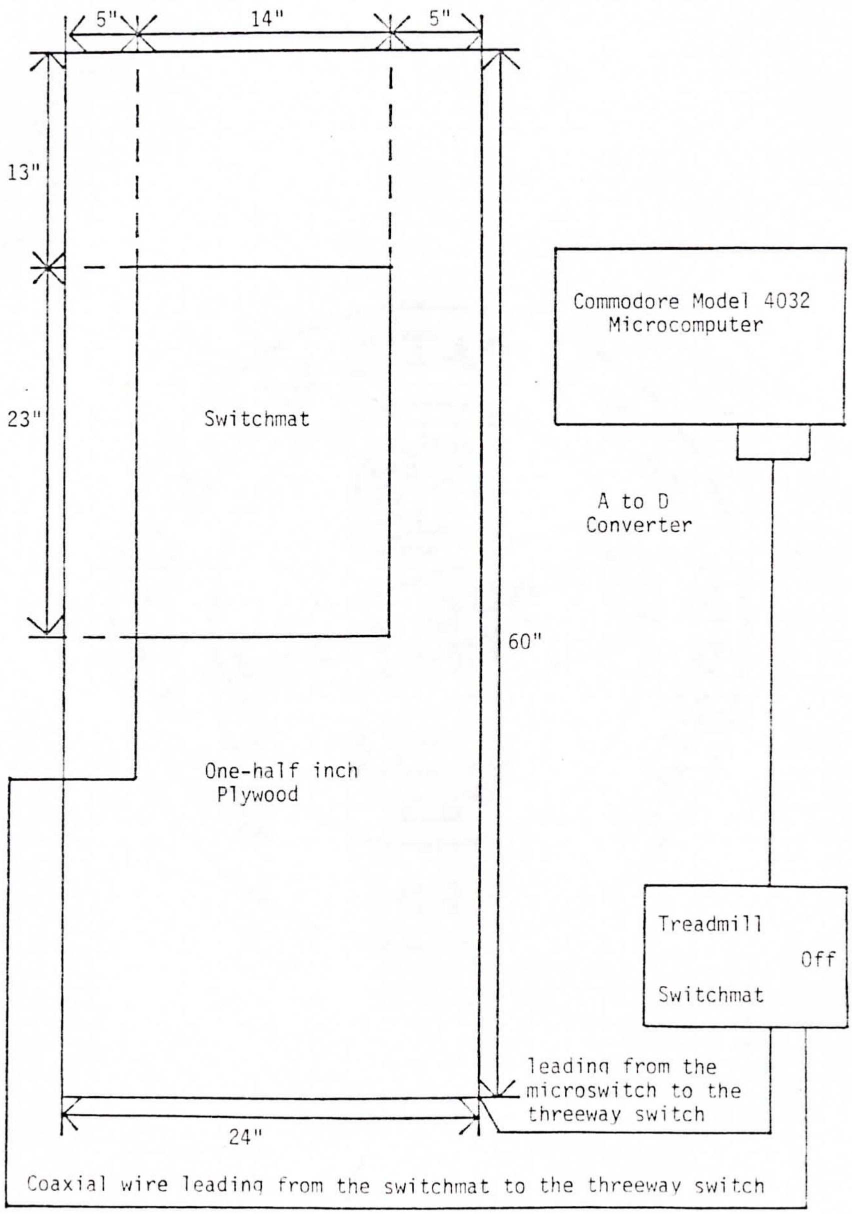

Figure 1. Diagram of the Equipment Used to Determine Stride Length

position, hitting the return key and, after an adequate sampling of revolutions, hitting any key to stop the timing. Once belt speed had been determined stride length could be determined by setting the toggle switch to the switchmat position. Again, hitting the return key activated the timing for the switchmat and striking any key deactivated the timing of heel strikes. Timer cycles between heel strikes were recorded. The program used the time between heel strikes multiplied by the belt speed to calculate stride length. Stride length was normalized for differences between subjects' leg length and total body height (refer to Appendix D).

Data Analysis

The data collected were analyzed using Analysis of Variance (ANOVA) with repeated measures. The null hypothesis was tested at the .05 level of confidence. Partial correlation was used to determine the contribution of stride length and aerobic capacity to increased PWC. An ANOVA 2 x 2 factorial design was used to test the pre and post test data between males and females for all variables.

CHAPTER 3

Results

A two-way Analysis of Variance (ANOVA) with repeated measures was used to analyze the grouped data for the study. An ANOVA 2 x 2 factorial design with repeated measures was used to analyze the homogeneously grouped data. The results supported the rejection of the null hypothesis for PWC at an alpha level of $p \leq .05$. All other findings supported the null hypotheses, as stated previously, for the remaining variables. The homogeneous grouped data indicated that the female response to training was significantly different from the male response in stride length adaptation. This finding supported the research hypothesis.

The change in physical work capacity for the group is illustrated in Figure 2. The ANOVA means and F-value can be seen in Table 1. A significant difference was found when analyzing pre and post test data (F=50.86). As seen in Figure 2 the males and females contributed equally to the increase thus no interaction was indicated. The null hypothesis for PWC was rejected at the .05 level of confidence.

The maximal oxygen uptake showed no significant difference in pre and post test data. The null hypothesis was accepted for VO_2 (see Figure 3). No significant interaction was noted when the data were homogeneously grouped.

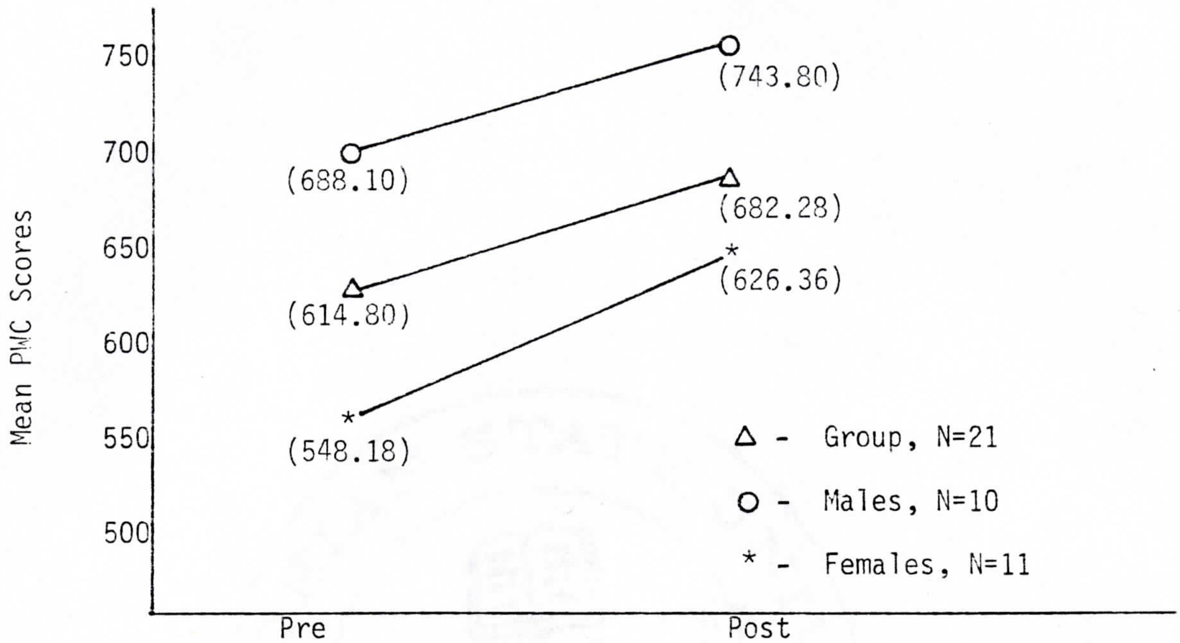

Figure 2. PWC (sec)

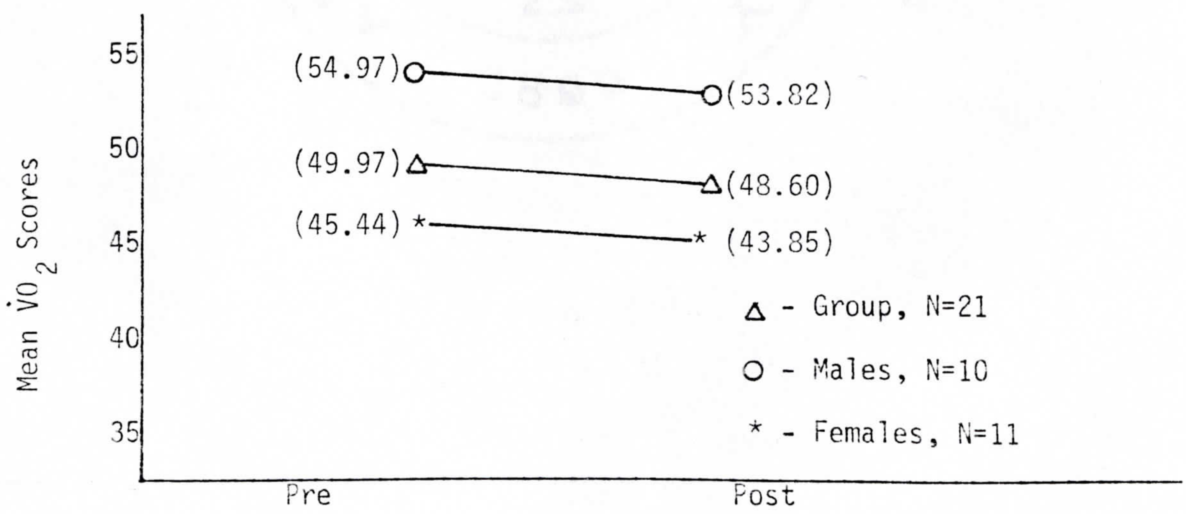

Figure 3. Oxygen Uptake (ml)

The analysis of the stride length data demonstrated a nonsignificant change in pre and post test data. While stride lengths were shorter as seen in Table 1, the change was not significant; therefore, the null hypothesis was accepted. The grouped data indicated a significant interaction between the males and females in the stride length variable. The interaction and group values can be seen in Figure 4 and Table 2 respectively. The null hypothesis was rejected at the $p \leq .05$ level as the homogeneous groups responded differently to treatment.

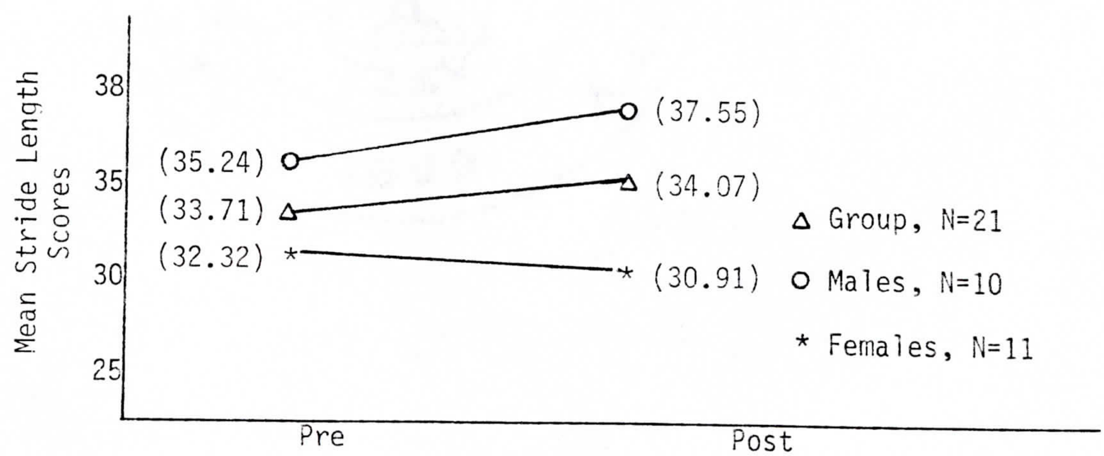

Figure 4. Stride Length (in.)

Table 1

ANOVA Table

Variable	Source	Sum S.	DF	Mean S.	F-value
PWC (sec)	TRT	47806.833	1	47806.833	50.86*
	Sub.	412680.906	20	20634.045	21.95
	Error	18798.617	20	939.31	
$\dot{V}O_2$ (ml/min)	TRT	19.886	1	19.886	0.79
	Sub.	3200.799	20	160.039	6.39
	Error	501.139	20	25.027	
SL (in)	TRT	1.362	1	1.362	0.22
	Sub.	812.868	20	40.643	6.47
	Error	125.553	20	6.278	

*Significant at $p \leq .01$

Table 2

ANOVA 2 x 2

Variable	Source	Sum S.	DF	Mean S.	F-value
PWC (sec)	TRT	46944.705	1	46944.705	51.04*
	TG	1323.739	1	1323.739	1.43
	Error	17474.867	19	919.729	
$\dot{V}O_2$ (ml/min)	TRT	19.545	1	19.545	0.74
	TG	0.488	1	0.488	0.018
	Error	500.650	19	26.350	
SL65 (in)	TRT	2.109	1	2.109	.044
	TG	36.239	1	36.239	7.70*
	Error	89.314	19	4.700	

*Significant at $p \leq .01$

CHAPTER 4

Discussion

Holloszy et al. (1977) and Miyamura et al. (1978) have noted the adaptive response to chronic aerobic exercise being manifested by an increase in oxygen utilization ($\dot{V}O_2max$) and concommitant improvements in performances. However, Costill (1979) noted that improved performances could be attained without an increase in oxygen uptake in trained runners. Thus, while oxygen uptake is a factor in improved performance it is not a limiting factor. The results from this study further support the concept of improved performance without increased maximal oxygen uptake. The subjects improved in PWC without a significant change in adaptive oxygen utilization at maximal levels. The minimal heart rates established for the subjects were set to impose an overload in order for the adaptative response of increased oxygen use to occur. The nonsignificant increase in maximal oxygen use following 11 weeks of training could be explained by the physiological adaptation of the body to do the same amount of work at a lower percentage of the reserve heart rate. Such an adaptation would occur if the resting heart rate decreased, making the body physiologically more efficient at work without increasing maximal oxygen utilization.

Powers, Hopkins and Ragsdale (1982) and Cavanaugh and Williams (1982) both noted a significant difference in efficiency when stride length was altered from the freely-chosen stride length. Cavanaugh and Williams (1982) further concluded that trained runners run at or near a stride length which is most energy efficient for a given speed. Nelson and Gregor (1976) noted a biomechanical change in stride length for trained runners over time with runners using shorter stride lengths and increased stride rate. Such mechanical changes were concommitant with improved performances. This study noted no significant adaptation in stride length for beginning runners after the 11 week training period. However, when homogeneously grouped, the male and female biomechanical response to the training was significantly different. As previously noted, the males developed longer strides at the same speed while the women developed shorter stride lengths with training. The adaptive response of the women in the group supported the literature suggesting the shorter stride length is more efficient and is an adaptation noted in trained runners. The male stride length response to training was not in agreement with the literature. Seymour (1985) studied lactate accumulation in trained runners and concluded that stride lengths used by distance runners were largely determined by the amount of lactate accumulation at a given intensity. The runners that accumulated greater lactate used longer relative stride lengths and were less skilled in running. Perhaps the males in this study lengthened their stride in the post test due to greater accumulations of lactate. However, it seems unlikely that the subjects would have increased in PWC and in the amount of plasma lactate as a result of training. Furthermore, the male subjects may have been more energy efficient through the lengthening of their strides rather than through shortening their strides. A final explanation for the different stride response of males and females might relate to the learning of a novelty task which would affect males and females differently. Males could have been more physically active in areas requiring the pre-development of an efficient stride length. Females may have been less active, therefore, opportunities to develop appropriate stride length, stride rate combinations may not have occurred prior to the 11 week training program. Thus, the female stride length response to the training program was in agreement with the literature.

Summary and Conclusions

The training program of 11 weeks of endurance running produced a significant increase in PWC as measured by the time completed on the BGET. However, these data would suggest that the increased PWC was not due to significant changes in maximum oxygen uptake or biomechanical adaptation of the stride length. While the stride length adaptations were not significant, the response was significantly different between males and females. The question of whether physiological change or biomechanical change contributes more to improved performance remains unanswered. However, this study does suggest that increased $\dot{V}O_2$ is not the major factor for increase performance. It does suggest that stride length could be a major contributor to improved performance. Furthermore, the study suggests that other biomechanical variables could have been responsible for an increase in efficiency regardless of stride length. Such variables as in-flight time, support time and stride rate could have been modified during training. Additional research must be conducted before the relative merits of physiological and biomechanical adaptations to performance can be conclusive. This study was unable to quantitatively define the precise contribution of either variable to improved performance.

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APPENDIX A

Tests Explanation

Tests Explanation

Bruce Graded Exercise Test

The Bruce Graded Exercise Test (BGET) will be used to test your maximal heart rate and oxygen uptake. The BGET is done on a treadmill and requires both an increase in speed and grade every three minutes. During this test a heart rate monitor will be worn. To measure the amount of oxygen that you are using, a mouthpiece will be worn and the air you exhale will be analyzed by a metabolic cart. In order to get accurate results the participant must stay on the treadmill as long as possible, preferably to exhaustion. For the average adult the BGET takes from 6 to 15 minutes to complete.

Stride Length Speed Test

The second type of test determines your stride length at a given percentage of your maximal oxygen uptake. For this test the treadmill will be set at zero percent elevation and the speed will be increased until you reach the desired level. When you reach the desired level and maintain this for three minutes then a stride length will be calculated. This test will take about 10-15 minutes.

Requirements for Both Tests

1. Be prompt!!! If possible arrive at least five minutes ahead of time. Tests will be done in the Human Performance Lab.

2. Wear comfortable shorts and a short sleeve shirt. Tennis shoes or running shoes should be worn, preferably the ones you will wear for training. Be sure to wear these same shoes for the post test.

3. Sign for test times which are during the same time of day, i.e., morning for both, late afternoon for both, etc.

4. Allow at least three hours between the last big meal and the test times. Small snacks will not negatively affect the results.

5. You must take both tests before starting the training and both post-test must be done within one week of the last day of training.

APPENDIX B

Questionnaire of Jogging Classes

Questionnaire of Jogging Classes

Name:

Purpose:

This questionnaire is designed to give the instructor some information about why you have selected this course, your background in running and goals you may have relative to this class.

1. Why did you select jogging and conditioning as an activities class?

   a. Am interested in starting to jog as a lifetime activity.
   b. Have been a runner before and wish to start again/continue.
   c. A fried is also taking the course.
   d. Needed the credit.
   e. Other (list)

2. List three goals which you think you would like to accomplish through this class.

Complete the following section if you are an athlete, former athlete or have ever run on a regular basis for more than a month.

1. If you are a former athlete, please list the sports in which you participated or are currently participating.

2. In training for the sport(s) did you ever do endurance runs? (More than 20 minutes at a steady pace) Yes No

3. Are you currently running on a regular basis?

4. If you are not running regularly, how long has it been since you ran regularly?

5. In running, how many days per week and miles per session did/do you run?

6. How long did you run or have you been running on a regular basis in terms of weeks, months or years?

APPENDIX C

Biometric Data

Biometric Data

Name: ______________________________

Height: _________________(in)

Weight: _________________(lbs)

Age: ___________

Leg Length: _________________(in)

Consent/Release Form

I fully understand the two test procedures as explained by the instructor and agree to participate in the tests as a pre and post measure of my improvement in class. I also understand that my class grade will not be affected by the results of the tests; however, failure to complete the tests as outlined will affect my class grade. I release Appalachian State University from any responsibility in case of injury or accident related to participation in this class and subsequent testing procedures. Further, I voluntarily agree to participate in the study and understand that I may withdraw from the study at any point.

____
(signed)

____
(date)

APPENDIX D

Example of Computer Printout for Stride Length

Example of Computer Printout for Stride Length

Subject: D. Messer
Treadmill Speed (MPH): 2.61411068
Stride Length: 27.909333
Leg Length/Stride Length: 1.3257214
Height/Stride Length: 2.38271549

Subject: D. Messer
Treadmill Speed (MPH): 3.44722938
Stride Length: 27.759161
Leg Length/Stride Length: 1.33289331
Height/Stride Length: 2.39560554

APPENDIX E

Bruce Graded Exercise Test

Bruce Graded Exercise Test

Stage	Minutes	Speed (mph)	Grade (%)
1	0-3	1.7	10
2	3-6	2.5	12
3	6-9	3.4	14
4	9-12	4.2	16
5	12-15	5.0	18
6	15-18	5.5	20
7	18-21	6.0	22

APPENDIX F

Bruce Graded Exercise Test

Bruce Graded Exercise Test

Name: ______________________________

Height: ________________

Weight: ________________

Leg Length: ____________

Minute	Heart Rate	$\dot{V}O_2$	SL/Stage
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

APPENDIX G

Stride Length Determination Test

Stride Length Determination Test

Name: ______________________________

Height: ________________

Weight: ________________

Leg Length: _____________

Max. $\dot{V}O_2$ ________________

65% $\dot{V}O_2$ ________________

65% Speed ________________

Minute	Heart Rate	$\dot{V}O_2$
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

APPENDIX H

Mean and Standard Deviation Table

Mean and Standard Deviation Table

Variable	Group	Pre-mean	St. Dev.(±)	Post-mean	St. Dev.(±)
PWC	G	614.80	112.673	682.28	94.226
	M	688.10	6.173	743.80	75.225
	F	548.18	82.530	626.36	73.759
VO2	G	49.97	10.655	48.60	8.459
	M	54.97	9.093	53.82	6.018
	F	45.44	10.248	43.85	7.642
SL65	G	33.71	4.532	34.07	5.135
	M	35.24	5.805	37.55	3.854
	F	32.32	2.059	30.91	4.036

VITA

Gaye Nell McConnell was born in Mooresville, North Carolina on December 5, 1958. She attended elementary schools in Iredell County and graduated from South Iredell High School in June 1977. In August 1977 she entered Appalachian State University and earned a Bachelor of Science degree in Physical Education. From August 1981 through June 1983 she was employed by Chesterfield County Schools at Cheraw High School, Cheraw, South Carolina. She taught physical education and coached varsity volleyball, women's basketball and varsity softball.

In August 1983 she entered Appalachian State University to work toward a Master of Arts degree in Exercise Science. Miss McConnell is currently employed by Rowan Technical College, Salisbury, North Carolina as the lead instructor for the Physio-Fitness and Health Technology Program.

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