8-1-1971

To Determine the Effect of Bicycle Ergometer Pedal-Arm Length on Heart Rate and Air Intake

John T. Nunn

TO DETERMINE THE EFFECT OF BICYCLE ERGOMETER PEDAL-ARM LENGTH ON HEART RATE AND AIR INTAKE

by
John T. Nunn

Bachelor of Science, University of North Dakota 1964

An Independent Study

Submitted to the Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Education

Grand Forks, North Dakota

August
1971 December 1971

This Independent Study submitted by John T. Nunn in partial fulfillment of the requirements for the Degree of Master of Education from the University of North Dakota is hereby approved by the Faculty Advisor under whom the work has been done.

W. C. Koenig
(Advisor)

Permission

Title TO DETERMINE THE EFFECT OF BICYCLE ERGOMETER PEDAL-ARM LENGTH ON HEART RATE AND AIR INTAKE

Department PHYSICAL EDUCATION

Degree MASTER OF EDUCATION

In presenting this independent study in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my independent study work or, in his absence, by the Chairman of the Department or the Dean of the Graduate School. It is understood that any copying or publication or other use of this independent study or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my independent study.

Signature John F Yunn

Date August 4, 1971

ACKNOWLEDGMENTS

My sincere gratitude and appreciation are offered to my advisor, Walter Koenig, for his invaluable guidance, assistance and patience throughout this study. Gratitude and appreciation are also offered to my wife, Gay, and daughter, Nancy-Sue, for their sacrifice and encouragement which has been beyond words.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

The purpose of this study was to determine the effect of bicycle ergometer pedal-arm length on heart rate and air intake. Nine students attending the University of North Dakota participated as subjects in the study. The subjects pedaled a bicycle ergometer for six minutes on three test days. The variable criterion for the three tests was the pedal-arm length which was altered to predetermined lengths of 15, 17 and 19 centimeters. Heart rate response and air intake volume were recorded and compiled at each minute of the six minute tests.

The raw data were statistically analyzed by two way analysis of variance and a Variance Ratio or F-test to determine significance at the 0.05 level. A means table for heart rate and air intake was established to determine possible trends and to aid in interpreting the results.

Based on the results of this study, it seems apparent that pedal-arm length effects heart rate and air intake during portions of the work output.

CHAPTER I

INTRODUCTION

Statement of the Problem

The purpose of this study was to determine the effects of length of the pedal arm on heart rate and air intake under prescribed test conditions on a bicycle ergometer. The resulting data and their analysis will provide researchers a better understanding about the equipment they are using.

Need for the Study

Bicycle ergometers are frequently used in physical fitness laboratories for investigating fitness and its many intricacies. It is a logical assumption that fitness investigators should be aware of structural changes on an ergocycle and the possible effect these changes have on test results.

Bicycles are ever increasing in use as a means of transportation, recreation and exercise. Perhaps pedal-arm length should be a major factor to be considered in purchasing a bicycle.

Delimitations of the Study

The writer delimited the study to:

1. a volunteer group of students attending the University of North Dakota,

2. students between the ages of twenty-four and thirty-six,

3. testing in the University of North Dakota Physical Educator Testing Laboratory.

Limitations of the Study

The following limitations must be taken into consideration when interpreting the results of this study:

1. the size of the test sample was a limitation in that nine students participated in the testing,

2. no control was exercised over the sleep, diet, daily habits and emotional make-up of the subjects,

3. there was no control over room temperature during testing,

4. interest may have affected test results in some cases.

Definition of Terms

Heart rate--the rate at which blood is pumped from the heart and surges through the arteries.

Air intake--the total volume of air which is inhaled into the lungs.

Ergometer--an apparatus for measuring the work performed by a group of muscles.

Review of Related Literature

A review of literature available revealed that many studies have been conducted using an ergometer. Fitness levels, cardiac output, oxygen uptake and training methods are the subject areas most

frequently studied when using the ergometer. The writer found no studies available which relate directly to the changing of pedal-arm length on an ergometer.

Most young physical educators think of the ergometer or ergocycle as a recent invention. Not so, Von Dobeln (1) reported in 1954 that an ergometer, if properly constructed, was an accurate means of measuring heart rate and respiratory rate under predetermined work loads. The fitness craze of the late sixties and which now continue has increased the use of bicycle ergometers as a means for measuring physical fitness. The ergometer continues to be a useful apparatus in research studies concerned with fitness and body functions.

Astrand and Rhyming (2) reported that in the first two to three minutes of work there is a rapid increase in ventilation, however the pulse rate and oxygen consumption usually reach a plateau between the third and fifth minute of light to moderate work. The body has an ability to adjust to work requirements and after a rapid beginning levels out to maintain a steady work output. As the work load continues in time, however, the heart must pump faster to meet body needs. Taylor (3) reported that during a prescribed work load the heart rate did not reach an absolute steady state but rather had a tendency toward a slow upward climb. A research study by Suggs (4) confirmed the findings of Astrand, Rhyming and Taylor when he also reported a rapid increase in heart rate from three to five minutes after which an equilibrium is reached, although the heart rate may climb slowly.

In a study to determine heart rate response within two different work loads using the same task, Alderman (5) found a high degree of

generality. The heart responses differed within the task but occurred at the same approximate time periods. It appeared that within work loads the heart rate response is highly predictable.

Evidence indicated that outside influences can affect heart rate response. Antel and Cummings (6) reported that an emotional factor can increase heart rate. An example cited of persons merely entering the testing laboratory and a resulting increased heart rate of the subject illustrates the phenomenon. Astrand and Saltin (7) also indicated that laboratory temperature can effect heart rate and respiratory response. Heart rate and respiratory levels can be effected by work loads and environmental conditions.

The regulation of breathing, its cause and effect, is a confusing situation to researchers. Astrand and Rodahl (8) reported that there are four factors which seemingly affect breathing: a chemical change in arterial blood, adrenalin, blood temperature and emotional levels. A number of theories have been advanced as to the role of the four factors in breathing, but none of them has fully explained how the respiratory volume is adjusted to meet the demand of rest and physical work.

CHAPTER II

METHODOLOGY

Introduction

In order to show the effect of pedal-arm length on heart rate and air intake, the nature of the problem included the analyses of the following:

1. number of heart beats per minute in three tests, each of a six minute duration,
2. number of liters of air inhaled in three prescribed tests, each six minutes in duration,
3. comparing the effects at the minute level of each test statistically, thus accepting or rejecting the null hypothesis.

The null hypothesis of the study was that there was no effect of varying pedal-arm length on heart rate and air intake responses. The alternate hypothesis was that a change in pedal-arm length would affect heart rate and air intake volumes.

Subjects

The subjects used for this study were nine students attending the University of North Dakota. The subjects ranged in age from twenty-four to thirty-six. Subjects were selected by reason of availability and volunteering to participate during the testing periods.

Reliability of Testing Methods

A review of the related literature indicated to the writer the reliability of the methods used for recording heart rate and air intake. The reliability of the ergocycle test-retest was previously established.

Test Used

The test used in this study consisted of each of the nine subjects pedaling an ergocycle on three prescribed days at three controlled pedal-arm lengths. In each of the three pedal-arm length tests a continuous recording for heart rate and air intake was recorded. Each of the three tests ran for six minutes.

Normal pedal-arm length for a Monarch ergocycle was 17 centimeters and was the criterion for one of the three tests. The other two tests used 19 centimeters and 15 centimeters for pedal-arm lengths.

For all three tests subjects pedaled the ergocycle at 50 rpm with three Kg's resistance. A metronome was used to ensure a constant pedaling rate during the three tests.

During the three tests, the heart rate was recorded with the aid of a Physiograph "Six" recorder. The minute readings were recorded on a score card for future reference (see Score Card, Appendix A, p. 20). Air intake was also measured at the end of each minute for the three six minute tests. This was accomplished by the subject inhaling all air through a Parkinson-Cowan CD-4 low-resistance flowmeter. Readings were recorded at the end of each minute during the six minute tests.

As mentioned earlier the testing was conducted three times with the variable factor being the pedal-arm length. After the three tests were completed and scored the individual scores were transferred to a master score card for analysis (see Master Score Card, Appendix B, pp. 21, 22, 23).

The analysis of data was done by means of treatment by subject design, two way analysis of variance with no replications within the cell. The heart rate and air intake group means were analyzed with reference to pedal-arm length to see if the means of the groups differed significantly.

The Variance Ratio or F-test was used to determine a significant level. With an 0.05 level of significance and two degrees of freedom a critical value of 3.63 was set up as the level for rejecting or accepting the null hypothesis.

CHAPTER III

ANALYSIS OF DATA

The study included the testing and gathering of data for three prescribed pedal-arm length tests on a bicycle ergometer. The two variables measured at one minute intervals were heart rate and air intake (see Master Score Card, Appendix B, pp. 21, 22, 23).

The raw data were subjected to a treatment by subject design including two-way analysis of variance and a Variance Ratio or F-test to determine significance at the 0.05 level.

Each minute of the three tests were compared statistically with corresponding minutes of the other tests to determine significance at the 0.05 level. Since there were six minutes in each of the three tests with two variables, heart rate and air intake, a total of twelve comparisons were made. There were twelve comparisons for heart rate and six comparisons for air intake.

Table 1 represents the heart rate comparisons with the variable pedal-arm lengths at the one minute level of the three tests. The F-ratio of 0.06 is not significant and the null hypothesis was accepted.

TABLE 1

HEART RATE COMPARISONS WITH VARIABLE PEDAL-ARM LENGTH AT ONE MINUTE

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	4.672	2.33	0.06
Individual Differences	8	5492.65	686.55	
Error	16	613.32	38.71	
Totals	26	6116.64		

To be significant F-ratio must equal 3.63.

TABLE 2

AIR INTAKE COMPARISONS AT ONE MINUTE WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	33.46	16.73	0.78
Individual Differences	8	2226.24	278.28	
Error	16	342.53	21.41	
Totals	26	2602.24		

To be significant F-ratio must equal 3.63.

Table 2 represents the air intake comparisons with pedal-arm lengths at one minute during the three prescribed tests. The F-ratio of 0.78 is not significant and the null hypothesis was accepted.

TABLE 3

HEART RATE COMPARISONS AT TWO MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	10.30	5.15	0.14
Individual Differences	8	5699.85	712.48	
Error	16	589.68	36.86	
Totals	26	6299.83		

To be significant F-ratio must equal 3.63.

Table 3 represents heart rate comparisons with the variable pedal-arm lengths at the two minute time period of the three tests. The F-ratio of 0.14 is not significant and the null hypothesis was accepted.

TABLE 4

AIR INTAKE COMPARISONS AT TWO MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	140.	70.04	4.07*
Individual Differences	8	1720.	215.05	
Error	16	275.43	17.21	
Totals	26	2135.91		

*To be significant the F-ratio must equal 3.63.

Table 4 represents air intake comparisons at two minutes with the variable pedal-arm lengths of the three tests. The F-ratio 4.07 indicates significance and the alternate hypothesis was accepted.

TABLE 5

HEART RATE COMPARISONS AT THREE MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	272.29	136.15	3.64*
Individual Differences	8	6298.75	787.34	
Error	16	599.00	37.44	
Totals	26	7170.04		

*To be significant F-ratio must equal 3.63.

Table 5 represents the heart rate comparisons at three minutes with the variable pedal-arm lengths. The F-ratio of 3.64 is significant and the alternate hypothesis accepted.

Table 6 represents air intake comparisons at three minutes with variable pedal-arm lengths. The F-ratio of 2.01 is not significant and the null hypothesis was accepted.

TABLE 6

AIR INTAKE COMPARISONS AT THREE MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	154.46	77.23	2.01
Individual Differences	8	1555.07	194.38	
Error	16	614.04	38.38	
Totals	26	2323.57		

To be significant F-ratio must equal 3.63.

TABLE 7

HEART RATE COMPARISONS AT FOUR MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	58.30	29.15	0.75
Individual Differences	8	5163.64	645.46	
Error	16	618.36	38.65	
Totals	26	5840.30		

To be significant F-ratio must equal 3.63.

Table 7 represents the heart rate comparisons at four minutes with variable pedal-arm lengths. The F-ratio of 0.75 is not significant and the null hypothesis is accepted.

TABLE 8

AIR INTAKE COMPARISONS AT FOUR MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	27.80	13.90	0.63
Individual Differences	8	2020.91	252.61	
Error	16	351.53	21.97	
Totals	26	2400.24		

To be significant F-ratio must equal 3.63.

Table 8 represents the air intake comparisons at four minutes with the variable pedal-arm lengths. The F-ratio is not significant and the null hypothesis was accepted.

TABLE 9

HEART RATE COMPARISONS AT FIVE MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	174.30	87.15	3.62
Individual Differences	8	5752.29	719.04	
Error	16	385.04	24.07	
Totals	26	6311.63		

To be significant F-ratio must equal 3.63.

Table 9 represents the heart rate comparisons at five minutes with variable pedal-arm lengths. The F-ratio of 3.62 is not significant and the null hypothesis was accepted.

TABLE 10

AIR INTAKE COMPARISONS AT FIVE MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	143.91	71.95	3.15
Individual Differences	8	1276.60	159.58	
Error	16	365.59	22.85	
Totals	26	1785.90		

To be significant F-ratio must equal 3.63.

Table 10 represents the air intake comparisons at five minutes with variable pedal-arm lengths. The F-ratio 3.15 is not significant and the null hypothesis was accepted.

Table 11 represents heart rate comparisons at six minutes with variable pedal-arm lengths. The F-ratio of 1.20 is not significant and the null hypothesis was accepted.

TABLE 11

HEART RATE COMPARISONS AT SIX MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	42.89	21.44	1.20
Individual Differences	8	5902.64	737.83	
Error	16	287.12	17.94	
Totals	26	6232.65		

To be significant F-ratio must equal 3.63.

TABLE 12

AIR INTAKE COMPARISONS AT SIX MINUTES WITH VARIABLE PEDAL-ARM LENGTHS

Source of Variation	df	S.S.	M.S.	F-ratio
Treatment	2	21.24	10.62	0.67
Individual Differences	8	1441.85	180.23	
Error	16	254.93	15.93	
Totals	26	1718.02		

To be significant F-ratio must equal 3.63.

Table 12 represents the air intake comparisons at six minutes with variable pedal-arm lengths. The F-ratio of 0.67 is not significant and the null hypothesis was accepted.

TABLE 13

HEART RATE MEANS

Pedal-arm Length	Means at One Minute Intervals					
	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.
15 c.m.	115.89	127.66	135.67	140.44	144.55	147.49
17 c.m.	116.56	126.22	127.88	137.22	144.44	147.5
19 c.m.	116.89	127.33	131.89	137.44	139.11	145.0

Table 13 presents the heart rate means of the subjects while pedaling at the three pedal-arm lengths. A trend indicates a steady but gradual increase of the heart from the one minute to six minute period of the testing.

TABLE 14

AIR INTAKE MEANS

Pedal-arm Length	Means at One Minute Intervals					
	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.
15 c.m.	32.61	45.56	51.06	51.39	55.55	57.56
17 c.m.	33.83	48.78	45.50	53.83	60.60	58.49
19 c.m.	31.11	43.22	49.89	52.22	55.89	59.71

Table 14 presents the means of the air intake volumes at each minute of the three tests. A trend developed and shows a steady and gradual increase from the one minute to the six minute period.

CHAPTER IV

DISCUSSION

The data which were collected represent the heart rate response and air intake volume during three six minute time periods. Pedal-arm length on a bicycle ergometer were the variable criterion for the three tests. The raw data were analyzed statistically by means of a two way analysis of variance and a Variance Ratio or F-test. Means tables were compiled for heart rate and air intake to observe possible trends in the two mentioned criterion variables and to illustrate which pedal-arm lengths required a higher response.

Observation of Tables 1 through 12 shows that two of the tables indicate a level of significance at the 0.05 level. The remaining ten tables indicate no significance at the criterion level. Table 4 representing air intake comparisons with variable pedal-arm length at the two minute period illustrates a significant F-ratio of 4.07. Table 5 representing heart rate comparisons with pedal-arm lengths at the three minute period illustrates a significant F-ratio of 3.64. The null hypothesis was rejected in both cases and the alternate accepted.

Table 13 represents the mean scores of the subjects while pedaling at three prescribed pedal-arm lengths. Observation of the three minute time period where significance resulted indicates that the 15 centimeter pedal-arm length required on the average a higher

response than the 17 centimeter pedal-arm length or 19 centimeter pedal-arm length.

Table 14 represents the air intake means of the subjects while pedaling an ergometer at three pedal-arm lengths. Observations at the two minute time period where significance resulted indicates that the pedal-arm length of 19 centimeters required an average higher response from the subjects than the 15 centimeter pedal-arm length or the 17 centimeter pedal-arm length.

Further observation of Tables 13 and 14 indicate a trend toward a higher heart rate response and air intake volumes as time progressed in the tests. The phenomenon of a steady state previously discussed in the Review of Literature, remains in doubt and is a subject area which should be questioned by further research studies.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Treatment of the data indicates that with pre-determined work loads and time periods used in this study that pedal-arm length effected heart rate during the three minute time period and that pedal-arm length effected air intake at the two minute time period. Within the limits of this study it is concluded that heart rate and air intake are not effected by pedal-arm lengths at all time periods within the prescribed tests.

Based on the review of literature and the foregoing study, the following recommendations are made:

1. Further investigation in this area should be conducted, and should include the using of a larger work load.
2. Regulation of the laboratory environment should be a primary concern of the investigator.
3. The investigator should allow subjects to familiarize themselves with breathing apparatus to be used.

APPENDIX A

SCORE CARD

Name_____ Date_____

Test #_____

Pre-test heart rate_____

Heart Rate Data

	1 min	2 min	3 min	4 min	5 min	6 min
Heart Rate						

Listing in beats per minute

Air Intake Data

	1 min	2 min	3 min	4 min	5 min	6 min
Air Intake						

Listings in liters

APPENDIX B

MASTER SCORE CARD

Pedal-Arm Length 15 Centimeters

Subject		Work Time					
H.R.	A.I.	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.
A	H.R.	120	129	138	138	143	145
	A.I.	30.5	42	45	49	55	52.5
B	H.R.	120	138	141	145	145	150
	A.I.	38.5	42.5	47	51.5	53.5	51
C	H.R.	105	120	129	138	138	141
	A.I.	32	48.5	56.5	49.5	56	51.5
D	H.R.	129	136	136	141	153	158
	A.I.	39.5	61.5	59	58	68.5	69
E	H.R.	90	102	107	113	113	116
	A.I.	13	35.5	42.5	33	33.5	45.5
F	H.R.	129	141	145	153	155	158
	A.I.	29.5	40.5	55.5	56	56.5	63.5
G	H.R.	94	108	127	130	138	138
	A.I.	21	34	39	47	49.5	51.5
H	H.R.	129	134	145	148	155	161
	A.I.	43	51	47	53.5	58	62
I	H.R.	127	141	153	158	161	163
	A.I.	46.5	54.5	68	64.5	69.5	71.5

A - I Subjects
H.R. Heart rate
A.I. Air intake

MASTER SCORE CARD

Pedal-Arm Length 17 Centimeters

Subject H.R. A.I.		Work Time					
		1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.
A	H.R.	122	136	132	136	138	143
	A.I.	22.5	36.5	37	48	56	54.5
B	H.R.	118	120	130	138	141	145
	A.I.	33.5	53.5	39	41.5	61	44.5
C	H.R.	103	117	125	130	138	138
	A.I.	34	46.5	36	52	58.5	59.5
D	H.R.	130	138	136	150	155	158
	A.I.	41.5	41.5	60	51	56.5	64.5
E	H.R.	78	82	78	102	108	108
	A.I.	24.5	45	42.5	42.5	59	50
F	H.R.	127	138	125	129	148	153
	A.I.	24.5	34.5	48	57	55.5	56.5
G	H.R.	107	117	125	134	143	148
	A.I.	28	40.5	30.5	44.5	51.5	53
H	H.R.	134	143	145	153	161	167
	A.I.	41.5	62	60.5	69.5	65	69.5
I	H.R.	130	145	155	163	168	168
	A.I.	54.5	60.5	64	63	70.5	70.5

A - I Subjects
H.R. Heart rate
A.I. Air intake

MASTER SCORE CARD

Pedal-Arm Length 19 Centimeters

Subject	H.R. A.I.	Work Time					
		1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.
A	H.R.	122	130	136	132	138	145
	A.I.	24	38.5	47.5	51	48.5	62
B	H.R.	122	132	141	150	150	155
	A.I.	36	40	50	52.5	53	56.5
C	H.R.	92	120	125	132	136	138
	A.I.	29	49.5	38.5	51	53	56
D	H.R.	132	134	130	141	148	153
	A.I.	40	52.5	57	57.5	62	69.5
E	H.R.	94	96	96	105	105	113
	A.I.	28	38	43	40	51	50.5
F	H.R.	120	136	141	150	132	148
	A.I.	15.0	32.5	60	51.5	59	53.5
G	H.R.	118	122	132	127	130	134
	A.I.	23	32.5	43.5	35	48	57
H	H.R.	127	138	138	145	155	158
	A.I.	39.5	48.5	56	59.5	60	65
I	H.R.	125	138	148	155	158	161
	A.I.	45.5	52	53.5	66	68.5	67.5

A - I Subjects
H.R. Heart rate
A.I. Air intake

SELECTED REFERENCES

1. Von Dobeln, W. "A Simple Bicycle Ergometer." Journal of Applied Physiology, VII (March, 1954), 222-4.

2. Astrand, P. O., and Rhyming, I. "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate During Sub-maximal Work." Journal of Applied Physiology, VII (1954), 218-21.

3. Taylor, C. "The Effect of Work Load on Heart Rate Studies in Exercise Physiology." American Journal of Physiology, CXXXV (1941), 27-42.

4. Suggs, Charles W. "An Analysis of Heart Rate Response to Exercise." Research Quarterly, XXXIX (March, 1968), 195-8.

5. Alderman, Richard B. "Interindividual Differences in Heart Rate Response to Bicycle Ergometer Work." Research Quarterly, XXXVIII (October, 1967), 323-9.

6. Antel, Jack, and Cummings, Gordon R. "Effect of Emotional Stimulation on Exercise Heart Rate." Research Quarterly, XL (March, 1969), 6-10.

7. Astrand, P. O., and Saltin, B. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity." Journal of Applied Physiology, XVI (November, 1961), 977-81.

8. Astrand, P. O., and Rodahl, K. Textbook of Work Physiology. New York: McGraw-Hill Book Co., 1970.

BIBLIOGRAPHY

Books

American Association for Health, Physical Education, and Recreation. Research Methods in Health Physical Education Recreation. Washington, D. C.: American Association for Health, Physical Education, and Recreation, 1959.

Morehouse, L. E., and Miller, A. T. Physiology of Exercise. 5th ed. St. Louis: The C. V. Mosby Company, 1967.

Snedecor, G. W., and Cochran, W. G. Statistical Methods. 6th ed. Ames, Iowa: The Iowa State University Press, 1967.

Articles

Astrand, P. O. "Work Tests with the Bicycle Ergometer." A. B. Cykel-Fabriken Monark, Varberg, Sweden, 1961.