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THE EFFECTS OF A HIGH SPEED, LOW RESISTANCE AND A LOW SPEED, HIGH RESISTANCE WARM-UP AT 50% $M\dot{V}O_2$ ON A LONG AND A SHORT TYPE OF PHYSICAL PERFORMANCE

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THESIS

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DEDICATION

I wish to dedicate this paper to my wife Shaaron whose encouragement and interest made the writing of this thesis possible.

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TABLE OF CONTENTS

Chapter Page

ABSTRACT

This study was designed to determine the effects of selected types of warm-up on a short and a long-type performance test on the bicycle ergometer. Eighteen subjects participated in this study and were blocked into three different fitness levels according to their $M\dot{V}O_2$. Each participant was subjected to a control condition (no warm-up), and to two kinds of warm-up exercises at 50% $M\dot{V}O_2$ on the treadmill: a condition where speed is relatively high and resistance low, and a condition where speed is relatively low but resistance high.

The criterion of warm-up for each experimental condition was a $0.8^{o}C$ rise above resting levels of rectal temperature. The time required to reach this criterion was recorded for each subject.

The performance test consisted of pedaling 35 revolutions (short-type performance) and 500 revolutions (long-type performance) in the least possible time on the bicycle ergometer.

The results showed that both high and average fitness groups performed significantly better ($P < .01$) than the low fitness group on the long duration type performance. No significant differences were found on the two types of performances after the three warm-up conditions. Similarly,

no significant differences were found between fitness levels and warm-up conditions on the time to reach the criterion temperature. However, a trend for the high speed, low resistance warm-up to reduce the time required to reach criterion temperature was observed.

It was concluded that warm-up, as defined in this study, does not enhance either a selected long-and short-type performance. As expected, relatively high fitness does enhance performance, particularly the long-type. It was also concluded that studies of the effects of types of warm-up, other than those used in the present study, are needed before a complete understanding of the relationship between warm-up and performance can be achieved.

LIST OF TABLES

LIST OF FIGURES

Definitions of terms and abbreviations:

$M\dot{V}O_2$: Maximal oxygen consumption

PWC_{130}: Physical Work Capacity at a heart rate of 130 beats/min.

High Fitness Level: Subjects with $M\dot{V}O_2$ ranging from 63.3 - 74.5 ml/Kg/min. (mean 67.1 $\pm$ 4.05 ml/Kg/min.)

Average Fitness Level: Subjects with $M\dot{V}O_2$ ranging from 55.2 - 59.7 ml/Kg/min. (mean 57.7 $\pm$ 1.93 ml/Kg/min.)

Low Fitness Level: Subjects with $M\dot{V}O_2$ ranging from 53.3 - 55.1 ml/Kg/min. (mean 50.3 $\pm$ 4.11 ml/Kg/min.)

Short-type Performance: Standard performance consisting of 35 turns on the bicycle ergometer lasting 12 to 15 seconds and simulates a 100m sprint.

Long-type Performance: Standard performance consisting of 500 turns on the bicycle ergometer lasting 3 to 5 minutes similar to the 1500m run.

CHAPTER I

INTRODUCTION

Preliminary exercise before strenuous performance is almost universally advocated by coaches and performers alike. The concept of warming the body before an activity and its effect on performance have long been of interest to the athletes and to the coaches in the field of competitive sports.

Athletes have used warm-ups before a strenuous activity for two common reasons: first, to prevent injuries during exercise; and second, to improve the quality of performance.

Morehouse and Miller (1970) have stated that a tearing loose of muscle fibers from their tendinous attachments may occur if a warm-up had not preceded the activity. However, other studies (Karpovich and Hale, 1956; Massey and Johnson, 1959; Mathews and Snyder, 1959; Skubic and Hodgins, 1957) have reported that no occurrence of muscle injury was found after either warm-up or no warm-up situations. Although it has been shown (Start and Hines, 1963) that warm-up had little effect on the incidence of muscle injury involving strength and speed activities, it did affect the number of injuries involving isotonic and isometric endurance.

Also of great interest to performers, coaches and physiologists are the expected benefits of warm-up upon performance and the physiological changes in the body that could be responsible for such an improvement.

Morehouse and Miller (1970) reported beneficial effects of warm-up on performance. They based their opinion on earlier reports of increases in the speed of muscle contraction and relaxation and also on increases in the force of contraction occurring when muscles have been warmed up just before activity.

Karpovich and Sinning (1971) stated that warming up was essential for good performance for many different reasons. They claimed that an increase in body temperature would help to augment blood circulation, blood volume, pulmonary ventilation, and oxygen transport. Lowering of the muscle temperature below normal would decrease muscle contractility and capacity for work. Therefore, if muscle is warmed up in some way before work, and especially before a competition, performance would increase.

In support of the above authors, Astrand and Rodahl (1970) stated that because metabolic processes are temperature-dependent, performances would benefit more from a higher temperature than from a lower temperature. They (Astrand and Rodall, 1970) reported that for each degree of temperature increase, the metabolic rate of the cell increases by about 13%, therefore increasing the rate of energy production.

Given the expected increases in blood and muscle temperature resulting from warming up, De Vries (1969) summarized the mechanisms responsible for an improved performance as: increased speed of contraction and relaxation of the muscles; greater efficiency due to lowered viscous resistance in the muscles; greater oxygen availability because of increased oxygen dissociation by haemoglobin; greater energy production because of the increased metabolic rate, and decreased resistance of the vascular bed. These mechanisms put together form the basis of the assumption that warming the body before any activity is beneficial for muscular performance.

A principal point of contention among researchers has not been whether to warm-up or not warm-up but rather the quality and quantity of warm-up necessary to bring about the desired improvements in performance. This has led many researchers in the past several years to conduct experiments in an attempt to quantify and qualify the warm-up necessary to enhance performance.

Saltin and Hermansen (1966) reported that subjects with different $M\dot{V}O_2$, working at the same relative work load, had similar increases in rectal temperature. However, they did not vary the speed and resistance in setting the relative work loads. Other researchers (Hipple, 1955; Lotter, 1959;

Mathews and Snyder, 1959) have reported the effects of warm-up on only one type of performance. Finally, no one has defined a standard warm-up by establishing a criterion rise in body temperature.

It appeared that a study was needed which quantified warm-up, using a criterion rise in body temperature and in which the speed and the resistance of the warm-up exercise was varied within a given relative intensity. Therefore, the subjects participating in this study, will work at 50% $M\dot{V}O_2$ under a condition where speed is relatively high and resistance low and under another condition where speed is relatively low but resistance is high. If intensity in terms of relative work load is the key to the time necessary to reach a criterion rise in core temperature, there should be no difference in this time between the warm-up conditions. If, however, it is the speed or resistance component of intensity which is critical, the times to criterion core temperature should vary.

It is also possible that the different modes of warm-up at the same relative intensity may differentially affect individuals of different fitness levels. Therefore, even though blocking subjects according to $M\dot{V}O_2$ is used statistically to attain more power, the blocks can be used to infer differential effects of warm-up on different fitness categories. Because of the controversial results on the effects of warm-up on physical performance, it also is of primary concern in this study to determine whether the increase of 0.8°C in core temperature enhances the performance on different work tasks.

Statement of the problems:

To determine whether relative intensity, speed, or resistance of exercise is more effective in achieving an increase in rectal temperature of approximately 0.8°C.

To determine whether warm-up to 0.8°C via increased speed and/or increased resistance at a 50% $M\dot{V}O_2$ enhances either a relatively long duration type of performance, a short duration type of performance, or both.

To determine whether there are any differential effects of fitness levels on time to reach a criterion temperature and on performances of either a long duration or a short duration exercise.

Limitations of the study:

The subjects in this study were 18 adult males (18-25 yrs) of varying fitness levels. Therefore, the results may be specific to this particular population.

Although an attempt was made to continuously measure the relative level of each subject's work, it was not possible to maintain an exact 50% $M\dot{V}O_2$ workload for all subjects.

Also, although the original experimental design called for all subjects to warm-up until rectal temperature rose 0.8^{o}C, not all subjects could fully achieve this criterion value.

Finally, no special experimental procedures were taken to control the psychological effects of the warm-up condition upon performance. Thus, it is possible that this factor did influence the results although standard test conditions were employed for each subject.

CHAPTER II

REVIEW OF LITERATURE

The effects of warm-up on performance have not yet been clearly established. Many physiologists have been conducting experiments for the past 20 years in an attempt to determine the necessity of warming up prior to engaging in vigorous physical activity.

Karpovich and Sinning (1971) have reported that 55% of all the recent research involving different warm-ups on different performances had no effect or were deleterious to the performances tested and 45% were of a beneficial nature. This shows the controversy that exists concerning the effects of warm-up on performance.

The various investigators interested in the subject have used different kinds of active preliminary work which can be grouped into warm-ups either related (Asmussen and Bøje, 1945; de Vries, 1959; Hipple, 1955; Karpovich and Hale, 1956; Mathews and Snyder, 1959; Michael, Skubic and Rochelle, 1956; Skubic and Hodgins, 1957; Thompson, 1958; Van Huss, 1963) or unrelated (de Vries, 1959; Michael Skubic and Rochelle, 1957; Muido, 1946; Pacheco, 1957) to the subsequent performance. Passive kinds of warm-ups, such as hot showers (Asmussen and Bøje, 1945; Carlile, 1956; de Vries, 1959; Muido, 1946; Robbins, 1942), radio diathermy, (Asmussen and Bøje, 1945; de Vries, 1959; Sedgwich and Whalen, 1964), and massage (Asmussen and Bøje, 1945; de Vries, 1959; Merlino, 1959), have also been used.

To determine the warm-up effect on performance many different activities such as those involving power and endurance on the bicycle ergometer, (Asmussen and Bøje, 1945; Karpovich and Hale, 1956; Massey, Johnson and Kramer, 1959), swimming (Carlile, 1956; de Vries, 1959; Muido, 1946; Thompson, 1958), running speed and endurance (Hipple, 1955; Karpovich and Hale, 1956; Mathew and Snyder, 1959; Sedgwich, 1964; Sills and O'Reilly, 1956), power in the vertical jump (Merlino, 1959; Pacheco, 1957), grip strength and different fine and gross motor skills (Burke, 1957; Lotter, 1959; Michael, Skubic and Rochelle, 1957; Robbins, 1942; Sedgwick and Whalen, 1964; Skubic and Hodgins, 1959; Van Huss, 1963) have been used. Consequently, the work of the investigators can rarely be compared and hence, a lot of confusion has resulted.

Other studies (Hipple, 1955; Mathew and Snyder, 1959; Massey, Johnson and Kramer, 1959; Pacheco, 1959) were concerned with the control of psychological factors associated with warm-up which could also influence performance. Only one study (Massey, Johnson and Kramer, 1959) reported that warm-up was a psychological rather than a physiological factor in improving performance. Therefore, little can be concluded from the research related to the psychological effect of warm-up upon performance.

In addition, some experiments (Hipple, 1955; Thompson, 1958) were so poorly controlled with such little warm-up activity (in terms of intensity and duration) that no conceivable physiological changes could have been achieved.

Thus, it appears that most investigators have employed a great variety of warm-up methods and performance tasks and have rarely attempted to reproduce the experimental conditions of other investigators. This has resulted in much confusion in the research on the warm-up effects on performance. Thus there appears a need to establish standard warm-up and performance tasks.

The research most pertinent to this study appeared to be that which utilized direct measurement of body and/or muscle temperature in assessing the effect of warm-up on performance. The study of Asmussen and Bøje (1945) has thrown new light on the subject by demonstrating that preliminary work resulting in increased muscle temperature enhances the capacity to perform two different types of tasks.

They demonstrated, in 4 healthy subjects, improvements of 3.5% to 8.0% in a performance lasting 12 to 15 seconds and 2.7% to 5.5% in a performance lasting 4 to 5 minutes on a bicycle ergometer when compared to performances under no warm-up. The preliminary work of 660 kgm/min. for 30 min. increased the rectal temperature an average of 0.8°C. No statistical analysis was performed to show if the reported percentage increases of the warm-up conditions were singificantly better compared to the no warm-up conditions. In an another experiment (Asmussen and Bøje, 1945) the two types of performance were improved when the body was heated by wave diathermy and hot shower (47°C) for about 10 minutes. In the short-type task, radio diathermy improved the performance from 4.7 to 6.6% and in the long-type from 3.9 to 7.6% on the 4 subjects. The rectal temperature was increased by about 1.5°C by radio diathermy. Only two subjects took the hot shower "warm-up" and they performed only the short-type task. Their performance was increased 5.0 and 7.2% over their no warm-up performance and their rectal temperature was increased by 0.5°C and 0.6°C, respectively. Again no statistical analysis was performed on the data. With the small number of subjects, it is unlikely that these improvements were significant.

Since the core temperature increases were quite small, they had one subject warm-up for various times (5-50 minutes) and subsequently perform a short-type performance while muscle temperature was recorded. Again, they reported improved performance with the improvements following the same time course as the rise in muscle temperature.

They concluded that the improvements were brought about by the increase in muscle temperature and not by the body (rectal) temperature. They showed that the best improvement was achieved when the muscle temperature had reached its peak level, i.e. after 10 to 15 minutes, and that the further slow increase in rectal temperature had but little effect on the performance.

Muido (1946) was also concerned with the influence of body temperature upon performance. His results demonstrated, in three subjects, that a rise in body temperature before swimming facilitates the performance. When the preliminary work consisted of 1,080 kgm/min. for 10 minutes on a bicycle ergometer, the results showed improvements of 1.4 to 2.6% in swimming time for standard events. The rectal temperature was raised to about 0.6°C. When 10 minutes of light gymnastics (jogging) was applied, the rectal temperature rose between 0.4 to 0.9°C and the performance of the same events were improved from 0.6 to 2.2%. He then conducted an experiment showing that rectal temperature 60 minutes following a Turkish bath type warm-up was still .4°C higher than the pre-warm-up rectal temperature while the muscle temperature had reached pre-warm-up levels or below. Yet, the performance times still showed an improvement of 1.2

to 4.3% after the 60 minutes. This implied that rectal rather than muscle temperature was more related to the improved performance.

Carlile (1956), in one of his experiments with 5 swimmers, found that the best performances were made when rectal temperature was above resting levels (37.3 - 38.3°C). He reported rectal temperatures elevated to 37.1-38.6°C in five subjects after 16 minutes of warm-up by hot shower at 40.5°C. When the performance time was correlated with rectal temperature, with the training effect partialled out, only one subject out of five had failed to improve his time. However, he concluded that for rectal temperatures below 38.1°C the performance time was in general less related to rectal temperature than to the muscle temperature. Unfortunately, the author in this study did not report muscle temperatures.

When using exercise as a warm-up, the investigators (Asmussen and Bøje, 1945; Carlile, 1956; Muido, 1946) have not quantified the preliminary work, therefore subjects have presented different increases in body temperatures before being tested on the performance tasks. Thus there appears a need to establish a standard warm-up by defining a criterion rise in body and/or muscle temperature.

The differences in the rise of the body temperature by the subjects is due to the fact that they were working at different relative work loads.

It was found by Saltin and Hermansen (1966) that the rise in body temperature was related to the relative work load, expressed as the percentage of the $M\dot{V}O_2$, and not to the absolute work load as was utilized in the above studies (Asmussen and Bøje, 1945; Carlile, 1956; Muido, 1946).

Clasing et al. (1968) failed to find differences in core temperature between persons with low and high $M\dot{V}O_2$ after 2 hr of work at a PWC_{130}. The load at PWC_{130} appeared to correspond to about 45% $M\dot{V}O_2$ (Kozlowski et al. 1972).

Kozlowski et al. (1972) also agreed with the findings of Saltin and Hermansen (1966). During exercise up to 50 minutes at relative loads of 35 and 50 percent of the $M\dot{V}O_2$, no differences were found in the internal body temperature between the high $M\dot{V}O_2$ and low $M\dot{V}O_2$ groups. They (Kozlowski et al. 1972) found only statistically significant differences ($P < .001$) with a relative load of 65% $M\dot{V}O_2$ and only after 45-60 min. of exercise.

The above findings would imply that subjects of varying physical performance capacity, as reflected by their $M\dot{V}O_2$, would require the same time of work at a fixed relative load, such as 50% $M\dot{V}O_2$, to reach a criterion body temperature.

In summary no experimental evidence exists in the review of literature to justify that warm-up is beneficial for good performances. Also, no definite conclusion can be drawn from these investigations because of the small number of experiments, the small number of subjects, the conflicting results, and the wide differences in warm-up and performance techniques.

Therefore, it was the purpose of this study to quantify the warm-up by establishing a fixed criterion body temperature of 0.8°C above resting levels. To standardize the intensity of the warm-up exercise, all subjects were "warmed-up" at 50% of $M\dot{V}O_2$.

A short and a long-type activity on the bicycle ergometer was used in this study in order to observe the differential effects, if any, of warm-up on performance.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Table I gives the mean $M\dot{V}O_2$, ages, and body weights of the eighteen subjects who participated in the study.

Physical conditions in the laboratory

The mean temperature in the laboratory was 23.9°C (range 22°C-25.1°C).

Apparatus

A Quinton treadmill was used to test the $M\dot{V}O_2$ of the subjects. They were warmed-up on the same instrument where speed and resistance (% grade) were set. During this procedure, the oxygen uptake was recorded on the Narco Bio-Systems Physiograph Four B. The analysis of the oxygen and the carbon dioxide were performed using the Godart Rapox and Capnograph, respectively.

The performance tests were done on a Monark bicycle ergometer fitted with a Marietta counter to record pedal revolutions. Standard stop watches and clocks were

FITNESS LEVELS	MVO_2		Age (years)	Body weight (kg)
	ml/kg/min	l/min		
BLOCK I	67.0	4.30	23.	64.2
BLOCK II	57.7	4.07	24	70.6
BLOCK III	50.3	3.70	24	73.9

TABLE I SELECTED ANTHROPOMETRIC AND PHYSIOLOGICAL CHARACTERISTICS OF THE THREE FITNESS BLOCKS used to record performance times.

Rectal temperature was monitored using a rectal thermocouple inserted to a depth of 15 cms. (Mead, 1949; Nielsen and Nielsen, 1962). The thermocouple output was fed into a Yellow Spring telethermometer to get a visual read-out of rectal temperature. Where sensitivity of read-out greater than that available from the telethermometer was needed, a Grass Model 5-P amplifier-recorder system was used.

Rapid calculations of % $M\dot{V}O_2$ were achieved by pre-programming a Wang 600 desk calculator.

Calibration of the laboratory instruments

Two test gases were verified for % O_2 and % CO_2 by the micro-Scholander technique and then used to calibrate the oxygen and carbon dioxide analysers before testing each subject.

The rectal temperature was monitored on the Grass recorder during the experimental warm-up conditions. A telethermometer connected to the Grass was used for this calibration and also used for direct visual readings of the rectal temperature of the subjects. A closed thermos containing water at a temperature close to body temperature (35-36^oC) was used to obtain a constant temperature when calibrating the Grass recorder with the resting temperature of the subjects.

Warm-up treatments

The treatments consisted of three warm-up conditions, B_1, B_2, B_3:

Treatment B_1 consisted of the control condition (no warm-up).

Treatments B_2 and B_3 involved warming up at 50% $M\dot{V}O_2$ with the grade of the treadmill set at 5% and 15% respectively with the initial speed calculated by the Balke formula given below.

Work load calculation for treatments B_2 and B_3

The work load for the warm-up conditions B_2 and B_3 was calculated using the empirical formula of Balke (1961) where:

VO_2 = Speed of treadmill x body weight x 1.8 (0.073 + OC)

Estimated VO_2 (50%) was in ml/min;

Speed of treadmill in meters/min:

Body weight in kilograms;

Factor 1.8, oxygen consumption in ml.;

Factor 0.073 was a factor which closely assessed the vertical lifting of weight during walking;

OC was the grade of the treadmill in %;

Knowing the VO_2 at which the subjects were to work (50% $M\dot{V}O_2$) and also their weight, the initial speed of the treadmill could easily be calculated and set at the start of warm-up exercise. The speed was then adjusted, if necessary, to keep the subjects' workload as close to 50% $M\dot{V}O_2$ as possible.

Performance tests

The performance tests were administered as follows:

a) A short-type performance consisting of pedaling as rapidly as possible thirty-five revolutions on the bicycle ergometer set at a constant resistance of 4 kiloponds (kps.).

Subjects, prior to the test, were given a count down of five revolutions so that at zero revolution (the go signal), the stop watch, the counter, and the performance could be started at the same time.

b) A long type performance consisting of pedaling 500 revolutions in the least possible time on the bicycle ergometer set at a resistance of 2kps. The same count down technique was used as in the short-type performance.

After the warm-up treatment but prior to the short-type performance test, a two-minute rest on the bicycle ergometer was allotted to each subject. Between the short- and long-type performance another two-minute rest was given to each subject.

Physiological parameters

Selected physiological measurements were taken during each warm-up treatment and performance test.

The rectal temperature in the no warm-up situation was measured for 15 minutes. Subjects were told to stand in an upright position during this resting period.

In treatments B_2 and B_3, the resting rectal temperature was recorded during the five minutes prior to engaging in the warm-up exercise and also in a standing position. During the warm-ups it was measured every three minutes until a criterion temperature of $0.8^{o}C$ above resting level was reached. The rectal temperature was also monitored throughout the performance tests.

The oxygen consumption was also measured every three minutes during the experimental treatments and was kept as closest possible to the subject's 50% $M\dot{V}O_2$.

Test procedures

Pre-test

Eighteen subjects had their $M\dot{V}O_2$ measured on the treadmill employing the method used in the Laboratory of the University of Ottawa (Thoden, personal communication). This test was applied prior to any testing.

All participants were then given the opportunity to practice the performance tests on the bicycle ergometer during a pre-trial session in order to minimize any possible learning or differential learning effects. The time scored on the short-and long-type performances in the pre-test were used to set exemplary times for performances in the experimental sessions.

Test

Subjects then participated in each of the three experimental conditions with the order being randomly assigned. During each test session each subject was rested, warmed-up, rested, performed, and then recovered. The rest, warm-up, and performance procedures were as previously described.

Before each testing session, all eighteen subjects in all three treatments knew their time score on the bicycle ergometer made in the pre-trial test. During the performance test all subjects worked in front of the revolution counter and the stop watch so that they were aware of the revolution and the time.

Positive reinforcement were given by the tester when needed (especially near the end of the long-type performance test), but no strategies nor tactics was given to any performer at the beginning or during each test.

All five sessions ($M\dot{V}O_2$, pre-test, and the three test sessions) were done during evenings with minimum of two days between each session.

Experimental design

The experimental design used a 3 X 3 factorial design (fixed model) with repeated measures on factor B (treatments) (Keith, 1972).

Factor A was fitness level. All eighteen subjects were blocked into three levels of fitness by their $M\dot{V}O_2$ with six subjects in each block.

Factor B was warm-up treatment. The three levels of factor B were:

a) B_1-no warm-up condition (control treatment);

b) B_2-warm-up condition with low resistance and high speed working at 50% $M\dot{V}O_2$:

c) B_3-warm-up condition with high resistance and low speed working at 50% $M\dot{V}O_2$.

Statistical analysis

The dependent variables were:

a) the time to complete 35 revolutions (secs.), short-type performance;

b) the time to complete 500 revolutions (secs.) long-type performance;

c) the time to reach criterion temperature (mins).

A two-way analysis of variance was used to determine which, if any, main effects were significant in the long-type performance, short-type performance and in the time to reach criterion temperature. If significant F-ratios were obtained, a one-way analysis of variance between groups was executed to test simple main effects. If the one-way anova was significant, a Newman-Keuls test was used as a comparison between individual means.

CHAPTER IV

RESULTS AND DISCUSSION

Results

The data of each individual in each fitness block for all treatments are given in appendix A - I, II, III.

The mean times for each fitness block for the long and short performance tests in seconds and the mean for the working time to reach criterion temperature in minutes are given in Tables II, III, and IV respectively.

Long-type performance

On the long-type performance, the higher the fitness level the better was the performance (Figure 1). However, only the differences between blocks I and III and blocks II and III were statistically significant ($p < .01$). (Appendix B-I).

The mean times of all subjects on the control and on the two experimental warm-up conditions tended to show (Figure 1) that the performance was better in a control condition rather than after warm-up exercises although mean differences were not significant.

The statistical tables are located in appendix B-I.

Short-type performance

Subjects from a relatively high fitness level (block I) performed better in this performance test than subjects from

	TREATMENTS			
Fitness Levels	Control Group B_1	Low Resistance High Speed B_2	High Resistance Low Speed B_3	Mean ±SE*
Block I 67.1 ± 4.05 ml/kg/min.	213.3 ± 7.3	216.3 ± 7.3	229 ± 11.1	219.5 ± 8.1
Block II 57.8 ± 1.93 ml/kg/min.	239.5 ± 10.9	237.5 ± 8.4	242.16 ± 9.2	239.7 ± 9.7
Block III 50.3 ± 4.11 ml/kg/min.	273.0 ± 9.8	276.5 ± 10.6	276.5 ± 13.7	275.3 ± 10.4
MEAN ±SE	241.9 ± 5.9	243.4 ± 5.7	249.2 ± 6.5	244.85 ± 5.9

TABLE II MEAN (±SE) TIME TO COMPLETE LONG PERFORMANCE (SECS.) AFTER DIFFERENT WARM-UP CONDITIONS

* Performance time between Block I and Block III and performance time between Block II and Block III, significantly different at $P. < .01$.

Fitness Levels	TREATMENTS			
	Control Group B_1	Low Resistance High Speed B_2	High Resistance Low Speed B_3	Mean ±SE
Block I 67.1 ± 4.05 ml/kg/min.	12.0 ± .12	12.3 ± .19	12.2 ± .30	12.0 ± .20
Block II 57.8 ± 1.93 ml/kg/min.	12.8 ± .39	13.2 ± .68	12.8 ± .66	12.9 ± .54
Block III 50.3 ± 4.11 ml/kg/min.	13.3 ± .29	13.4 ± .29	13.3 ± .54	13.4 ± .35
MEAN ±SE	12.7 ± .17	12.9 ± .23	12.8 ± .27	12.5 ± .22

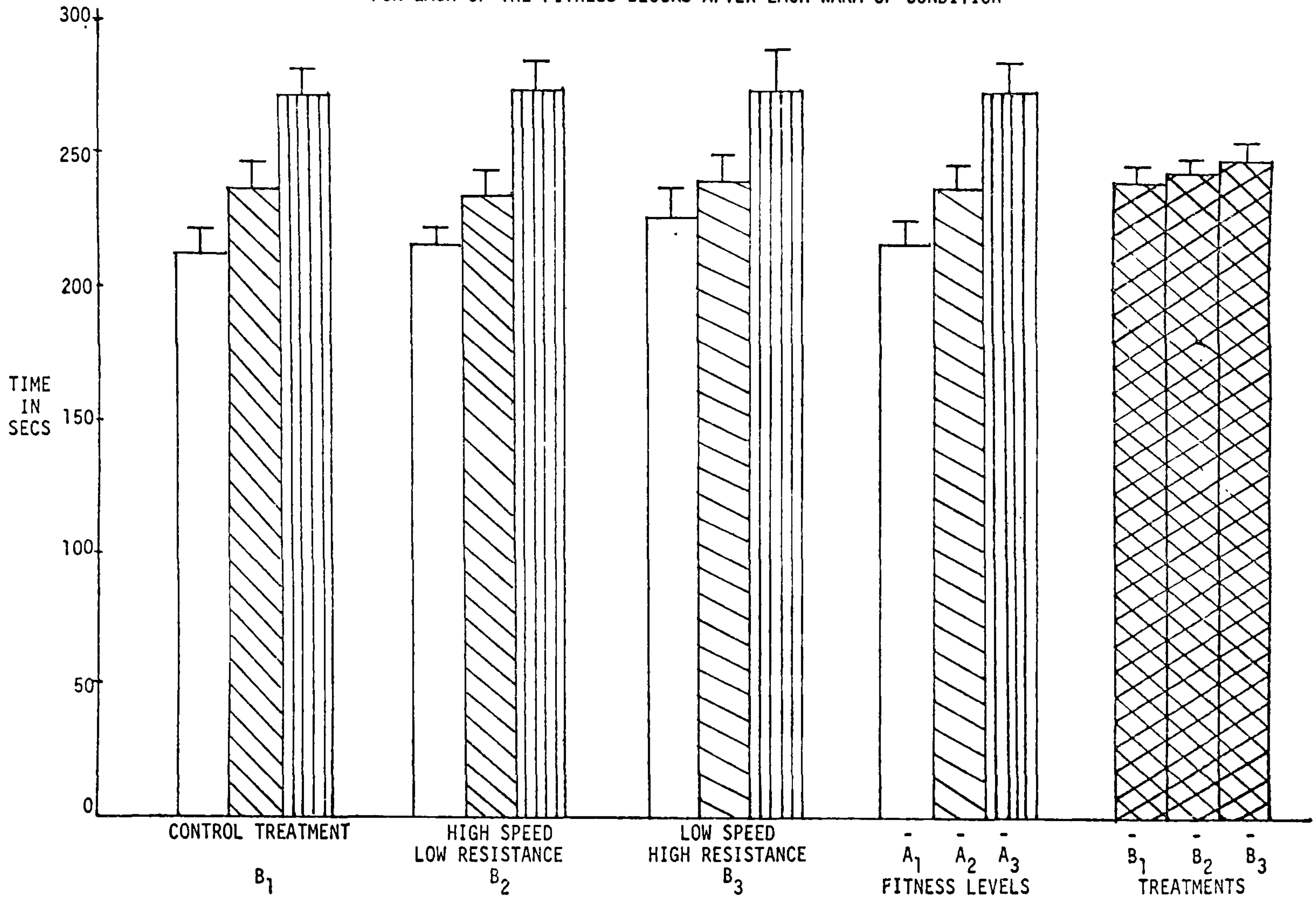
TABLE III MEAN (±SE) TIME TO COMPLETE SHORT PERFORMANCE (SECS.) AFTER DIFFERENT WARM-UP CONDITIONS

	T R E A T M E N T S			
Fitness Levels	Control Group B_1	Low Resistance High Speed B_2	High Resistance Low Speed B_3	Mean ±SE
Block I 67.1 ± 4.05 ml/kg/min.	--	22.50 ± 3.0	24.76 ± 2.5	23.63 ± 2.5
Block II 57.8 ± 1.93 ml/kg/min.	--	24.16 ± 1.2	33.97 ± 9.7	29.06 ± 2.8
Block III 50.3 ± 4.11 ml/kg/min	--	30.54 ± 3.0	28.29 ± 2.0	29.41 ± 2.3
MEAN ±SE	--	25.73 ± 1.3	29.00 ± 1.5	27.36 ± 1.4

TABLE IV MEAN (±SE) WORKING TIME TO REACH CRITERION TEMPERATURE AFTER DIFFERENT WARM-UP CONDITIONS

FIGURE 1

PERFORMANCE TIMES (SEC.) ON THE LONG TYPE PERFORMANCE FOR EACH OF THE FITNESS BLOCKS AFTER EACH WARM-UP CONDITION*



A_1 - Block I

A_2 - Block II

A_3 - Block III

Treatments

* Performance time between block I (high fit) and block III (low fit) and performance time between block II (average fit) and block III (low fit) are significantly different at $P < .01$.

FIG''RE 2 FOR EACH OF THE FITNESS BLOCKS AFTER EACH WARM-UP CONDITION

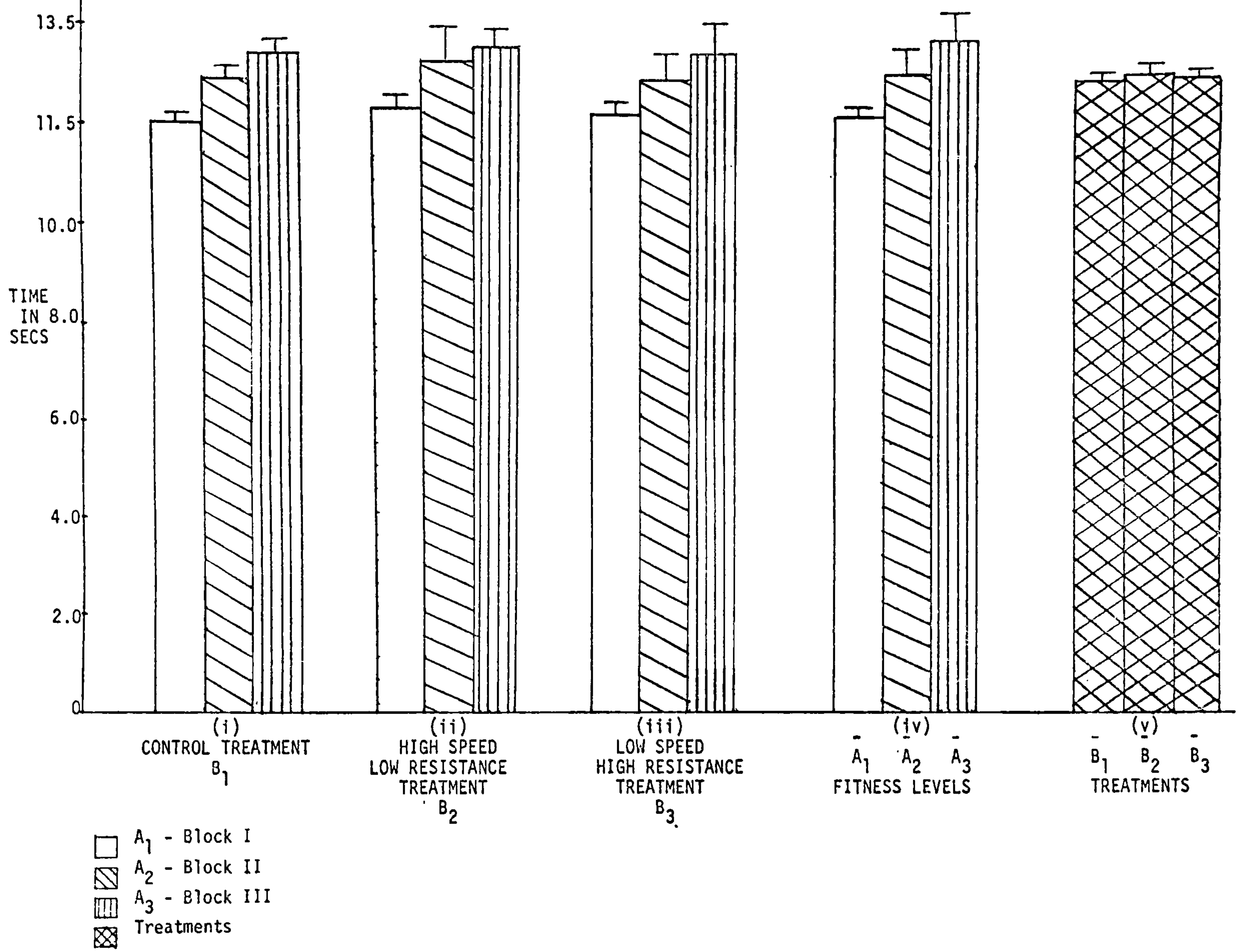
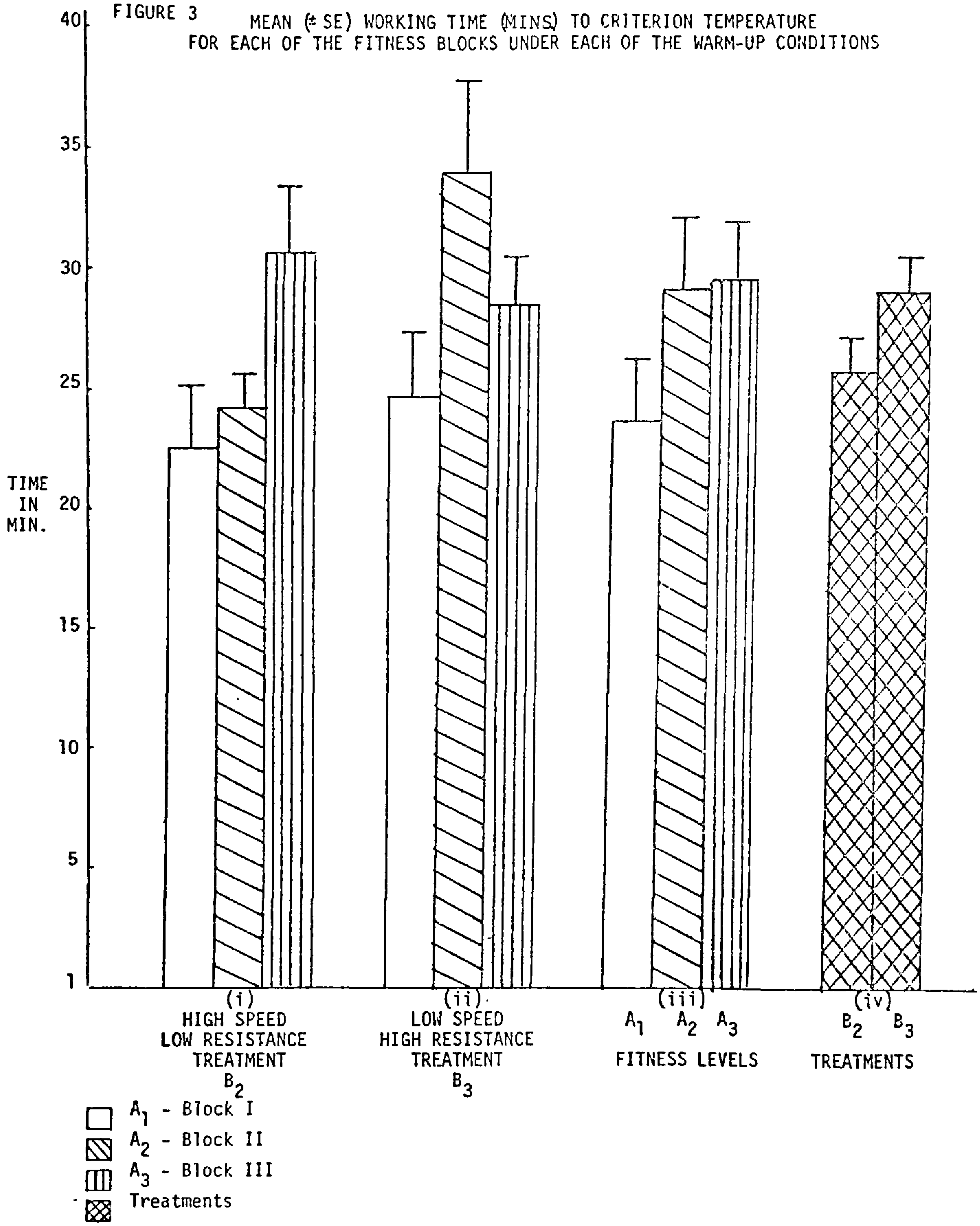


FIGURE 3 MEAN (± SE) WORKING TIME (MINS) TO CRITERION TEMPERATURE FOR EACH OF THE FITNESS BLOCKS UNDER EACH OF THE WARM-UP CONDITIONS



a relatively average or low fitness level (block II and III) (Figure 2), however no significant F-ratio was shown on the two-way ANOVA, (appendix B - II), thus a further statistical comparison was not warranted.

When the mean times of this performance for all subjects were compared between the three warm-up treatments (Figure 2) no significant differences were obtained (appendix B - II).

Working time to reach criterion temperature

Although the time to reach criterion temperature (Figure 3) was faster in the high fitness block than in the other two blocks, these differences were not statistically significant (appendix B - III).

The experimental condition consisting of high speed and low resistance warm-up was faster in increasing the body temperature 0.8^{o}C than the condition consisting of high resistance and low speed (Figure 3), however, no significant differences were found between the mean times for the three treatments (appendix B - III).

Pre and post-warm-up rectal temperatures

Pre- and post-warm-up rectal temperatures for each fitness block are given in Appendix A-I to A-III.

The results showed that only the high fit group (block I) fully achieved the criterion 0.8°C rise in rectal temperature after the two warm-up treatments (B_2 and B_3). Unexpectedly, both the Block II and III subjects fell short of the criterion on both warm-ups; 0.79°C and 0.74°C for block II and 0.66°C and 0.75°C for block III.

Discussion

The finding of a significant difference ($p < .01$) in the time to pedal 500 revolutions between different fitness groups was to be expected in this study. Asmussen and Bøje (1945) have reported that such a performance would stress the respiratory and circulatory systems and, therefore, subjects with a relatively high $M\dot{V}O_2$ would tend to do better in this performance than subjects with relatively lower $M\dot{V}O_2$ (Figure 1).

No statistical significance was found in the time to pedal 35 revolutions among different fitness levels (Figure 2). According to Asmussen and Bøje (1945) this type of performance would mainly be performed anaerobically, therefore the aerobic system would not be expected to influence the performance time. It is interesting to note, however that even though the differences were not statistically different, the relatively high fit caterogies tended to perform better on this type of task. Although the $M\dot{V}O_2$ test, which was used to block subjects into fitness categories, is used as a measure of aerobic power, the ability to perform the higher workloads in this test also demands substantial anaerobic capacity. It is therefore probable that the trend displayed in this study on the short-type performance test reflects higher anaerobic capacities in the higher fit groups.

The results reported by Asmussen and Bøje (1945) that warm-up was beneficial to two types of performance can't be attributed to the difference in fitness levels of their subjects, because they did not classify their subjects on $M\dot{V}O_2$, but were only reported as four healthy subjects.

In this study no differences appeared between the three warm-up conditions on the long and short-type performance tests (Figure 1-2). These findings do not support the results of Asmussen and Bøje (1945) who found an improvement in performance time after a warm-up condition when compared to a no warm-up situation. No statistical analysis was done by the authors (Asmussen and Bøje, 1945) on their results. The present author performed a one-way ANOVA to Asmussen and Bøje's (1945) experiment to determine if their results were significant. The statistical analysis revealed that significant differences ($p < .05$) existed in the short-type performance (35 revolutions) but not in the long-type performance (450 revolutions). Their results which showed improvement in the short-type performance after warm-up may be related to the fact that their four subjects were all very high fit. The inability to reproduce their results in the present study may be due to the different fitness range of the eighteen subjects utilized here.

The results of the present study revealed no significant differences in the time to perform a short duration type performance and a long duration type performance after two different kinds of warm-up. The body temperature was increased to an average of 0.75°C after a warm-up condition consisting of low resistance, high speed and increased to an average of 0.76°C after a condition consisting of high resistance, low speed. Although De Vries (1969) has reported important physiological changes in helping to improve performance with a rise in body temperature, the present study did not support the contention that a rise in body temperature of about 0.8°C is beneficial in improving performance.

It is possible that the increase in core temperature of about 0.8°C failed to ellicit the physiological changes reported by De Vries (1969) such as: increased speed of contraction and relaxation of the muscles; greater efficiency due to lowered viscous resistance in the muscles; greater oxygen availability because of increase oxygen dissociation by haemoglobin; greater energy production because of the increased metabolic rate and decreased resistance of the vascular bed, and therefore, this rise in core temperature would not result in improved performance.

However if the rise in core temperature ellicited changes in the above physiological parameters these changes were not of sufficient magnitude to produce improved performance in the two types of work tasks used in this study.

Another reason that results of the present study revealed no beneficial effects on two performances when body temperature was about 0.8^{o}C above resting level could be due to the low relative intensity of the work load (50% $M\dot{V}O_2$).

Therefore, since no improvements in performance were shown in the present study after a warm-up at 50% $M\dot{V}O_2$ to about 0.8^{o}C above resting level, it is suggested that further studies on warm-up at increased relative intensities be undertaken to determine if higher core temperatures are beneficial for performance.

The study which measured muscle temperature directly and implied that it was the main factor in improved performance did not find statistically significant improvements (Asmussen and Bøje, 1945). While in another study (Carlile, 1956) which inferred that muscle temperature was the primary factor, did not report the muscle temperature measurements. The results of the present study, then, also suggest the need for further experimental studies on the effects of warm-up on performance by comparing both muscle and core temperature with subjects of different fitness levels, working at a similar relative work loads.

The lack of a significant difference in the time to achieve a criterion rise in rectal temperature (0.8°C) between the three fitness groups comfirms the findings of Saltin and Hermansen (1966), Kozlowski et al. (1972) and Clasing et al. (1968). Even the trend for the high fit group to reach criterion faster than the average and low fit groups is suspect. This is because the lower fitness groups could not achieve the criterion fully and this inflated their work times.

At a 50% relative load, the resistance and speed were varied to determine if the type of warm-up would affect the time to reach a criterion temperature. The findings showed that the working time to reach a rise of 0.8°C did not reveal any significant differences between the warm-up treatments. Therefore, it would appear that the rise in body temperature is attributed only to the relative load of 50% $M\dot{V}O_2$ rather than to the way the load was performed (Figure 3).

It is interesting to note that even though the differences in time to criterion temperature between the two warm-up conditions were not statistically significant, the high speed, low resistance group tended to reach criterion temperature faster than the other group (Figure 3). Further research utilizing warm-ups of varying speeds and resistances is needed to establish if the high speed, low resistance type warm-up is a sufficiently beneficial technique to warrant its adoption by coaches and athletes.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It was concluded from the results of the present study that:

a) there were no significant effects of warm-up, as defined in this study, upon a selected short-and long-type performance;

b) the higher the fitness level the better was the performance, particularly performance of the long-type;

c) the time required to reach a standardized level of warm-up, defined as a rise of 0.8°C in rectal temperature, is not significantly affected by fitness level;

d) the use of a relatively low intensity warm-up (50% $M\dot{V}O_2$) failed to increase the rectal temperature 0.8°C in all subjects, particularly those of low fitness.

Recommendations

The results of this study suggested that further research is needed:

a) to determine if intensities of warm-up higher than the 50% $M\dot{V}O_2$ used in this study will cause higher core temperature which may be beneficial for different kinds of performance;

b) to determine if the effects of warm-up on performance depends more on muscle temperature, on body temperature, or on both;

c) to identify the specific relationships between relative intensity of warm-up, warm-up work time at a fixed relative intensity and the subsequent rise in muscle and/or body temperature.

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APPENDIX A

Raw data for individual subjects
within Block I-II-III

BLOCK I

HIGH $\dot{M}\dot{V}O_2$

67.1 ± 4.05
ml/kg/min.

#	Name	MVO_2 ml/kg/min.	TREATMENTS: Control Group B_1 Pre RT °C	Time in secs for 500 revs	Time in secs for 35 revs	B_2 Low Resistance High Speed Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.	B_3 High Resistance Low Speed Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.
1	P.L.	74.5	-	180	12.0	37.5	38.3	59	184	12.3	09.20'	37.8	38.6	43	197	11.1	20.00'
2	C.T.	68.0	37.0	207	11.6	37.2	38.0	51	214	11.5	15.33'	37.1	37.9	49	210	11.5	15.24'
3	J.B.	66.8	37.4	196	12.0	37.3	38.1	52	191	12.7	22.50'	37.5	38.3	45	190	12.3	21.00'
4	G.P.	66.1	37.5	246	12.2	37.7	38.5	53	252	13.6	29.66'	37.2	37.8	45	260	13.0	35.00'
5	J.P.A.	63.8	-	200	11.4	37.8	38.6	57	209	11.7	24.80'	38.7	39.5	51	215	11.0	20.60'
6	P.M.	63.3	37.6	251	12.8	37.6	38.4	60	248	12.3	33.50'	37.7	38.5	54	302	14.0	30.80'
MEAN		67.1 ±4.05	37.4	213.3 ± 7.3	12.0 ± .12	37.5	38.3	55.4	216.3 ± 7.3	12.3 ± .19	22.50' ±3.0	37.6	38.4	47.8	229.0 ±11.1	12.2 ± .3	24.76' ±2.5

RAW DATA FOR INDIVIDUAL SUBJECTS
WITHIN BLOCK I

APPENDIX A-II

BLOCK II

AVERAGE MVO_2

57.8 ± 1.93
ml/kg/min.

			TREATMENTS														
			B_1 Control			B_2 Low Resistance High Speed						B_3 High Resistance Low Speed					
#	Name	MVO_2 ml/kg/min.	Pre RT °C	Time in secs for 500 revs	Time in secs for 35 revs	Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.	Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.
1	R.M.	59.7	37.7	217	12.0	37.4	38.2	58	212	12.0	20.80'	37.3	38.1	49	217	11.1	20.20'
2	J.E.S.	59.5	-	200	11.5	37.8	38.6	61	194	10.3	21.10'	37.1	37.9	49	190	10.3	29.33'
3	S.C.	59.0	-	227	12.5	37.8	38.5	55	232	16.0	27.66'	37.5	38.3	46	234	15.5	49.66'
4	G.L.	57.2	-	230	11.8	38.1	38.9	54	254	11.5	27.80'	38.0	38.5	54	251	11.4	43.96'
5	P.A.	55.9	37.2	242	13.0	37.6	38.4	51	245	12.5	20.00'	37.4	38.2	49	273	12.0	30.50'
6	R.A.	55.2	37.8	321	15.7	38.0	38.8	56	288	17.0	27.58'	37.6	38.4	54	288	16.6	30.20'
MEAN		57.7 ±1.93	37.6	239.5 ±10.9	12.8 ± .39	37.8	38.6	56	237.5 ± 8.4	13.2 ± .68	24.16' ±1.2	37.5	38.2	50	242.16 ± 9.2	12.8 ± .66	33.97' ±3.5

RAW DATA FOR INDIVIDUAL SUBJECTS
WITHIN BLOCK II

BLOCK III

LOW MVO_2

50.3 ± 4.11
ml/kg/min.

			TREATMENTS														
			B_1 Control			B_2 Low Resistance High Speed						B_3 High Resistance Low Speed					
#	Name	MVO_2 ml/kg/min.	Pre RT °C	Time in secs for 500 revs	Time in secs for 35 revs	Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.	Pre RT °C	Post RT °C	% of MVO_2	Time in secs for 500 revs	Time in secs for 35 revs	Working time in min.
1	B.L.	55.1	-	227	14.4	38.2	38.8	51	238	15.0	40.26'	37.8	38.6	53	227	14.4	26.95'
2	G.J.	52.0	37.4	325	12.9	37.3	38.1	50	278	12.5	28.50'	37.7	38.5	47	289	11.0	27.00'
3	G.V.	51.9	37.8	309	15.0	37.5	37.8	46	339	14.2	15.83'	37.6	38.1	50	369	16.5	35.66'
4	L.L.	51.6	37.7	275	13.0	37.8	38.6	48	307	13.7	27.30'	37.7	38.5	49	293	14.0	30.36'
5	P.M.	48.1	-	239	11.8	37.7	38.5	49	231	11.8	39.50'	37.2	38.0	44	231	11.0	32.20'
6	F.V.	43.3	-	263	12.9	37.9	38.6	50	266	13.4	31.86'	37.7	38.5	50	250	13.0	17.60'
MEAN		50.3 ±4.11	37.6	273 ± 9.8	13.3 ± .29	37.7	38.35	49	276.5 ±10.6	13.4 ± .29	30.54' ±3.0	37.6	38.35	49	276.5 ±13.7	13.3 ± .54	28.29' ±2.0

RAW DATA FOR INDIVIDUAL SUBJECTS
WITHIN BLOCK III

APPENDIX B

Statistical Analysis of data obtained
for long and short performance and
the time to criterion temperature

APPENDIX B-1

Two Factor Analysis of Variance
With Repeated Measures
For Time on Long Type
Performance

Sources	SS	DF	MS	F	P
Between subjects	90443.	17			
A	28716.7	2	14358.3	3.48	$<.05$
Subject w. groups					
R:A	61727.	15	4115.1		
Within subjects	7796.0	36			
B	530.6	2	265.3	1.16	$<.32$
AB	414.7	4	103.6	.45	$<.76$
Treatment x subj. within groups					
BR:A	6853.	30	228.4		

One Way Analysis of Variance
for Time on Long Type Performance

Sources	SS	MS	DF	F	P
Groups	.2871	14358.0	2	.10.5	$<.0001$
Error	.6952	1363.2	51		

Newman-Keuls Comparison Between
Ordered Means for Time
on the Long Type Performance

Group Means	3 275.3	2 239.7	1 219.5
1- 219.5	55.77 **	20.16	
2- 239.7	35.61 **		
3- 275.3			

** Significant at α.01

Critical Differences	R = 2	R = 3
q. 99 (r, 51)$\sqrt{}$ms within /n	32.97	37.58
q. 95 (r, 51)$\sqrt{}$ms within /n	24.70	29.75

APPENDIX B-II

Two Factor Analysis of Variance
With Repeated Measures
for Time on Short Type
Performance

Sources	SS	DF	MS	F	P
Between subjects	121.6	17			
A	12.7	2	6.38	0.880	$<.43$
Subj. w. groups					
R:A	108.8	15	7.25		
Within subjects	19.8	36			
B	1.03	2	0.519	0.836	$<.44$
AB	0.27	4	0.067	0.109	$<.97$
Treatments x subj. w. groups					
BR:A	18.6	30	0.620		

One Way Analysis of Variance
For Time on Short Type Performance

Sources	SS	MS	DF	F	P
Groups	.12781	6.39	2	2.53	$<.08$
Error	.1287	2.52	51		

Newman-Keuls Comparison Between
Ordered Means for Time
on Short Type Performance

Group Means	3 13.36	2 12.92	1 12.1
1- 12.18	1.17	0.74	
2- 12.92	0.43		
3- 13.36			

APPENDIX B-III

Two Factor Analysis of Variance
With Repeated Measures
on Time to Criterion Temperature

Sources	SS	DF	MS	F	P
Between subjects	1581.37	17			
A	299.016	2	149.5	1.74	$<.20$
Subj. w. groups					
R:A	1282.34	15	85.4		
Within subjects	970.66	18			
B	78.25	1	78.2	1.77	$<.20$
AB	230.97	2	115.4	2.61	$<.10$
Treatments x subj. within each group					
BR:A	661.43	15		44.0	

One Way Analysis of Variance
on Time to Criterion Temperature

Sources	SS	MS	DF	F	P
Groups	0.25217	126.09	2	1.84	$<.174$
Error	0.2255	68.35	33		

Newman-Keuls Comparison Between
Ordered Means for
Time to Criterion Temperature

Group Means	3 29.41	2 29.06	1 23.63
1- 23.63	5.78	5.43	0.0
2- 29.06	0.35	0.0	0.0
3- 29.41	0.0		