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THE EFFECT OF
PRELIMINARY EXERCISE
ON SPEED AND ENDURANCE PERFORMANCE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled The Effect of Preliminary Exercise on Speed and Endurance Performance

submitted by David Baily Stuart

in partial fulfilment of the requirements for the degree of Master of Science

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ABSTRACT

The primary purpose of this research was to investigate the effect of two varying preliminary exercise intensities on a speed and endurance task on the bicycle ergometer.

The secondary purposes were to determine the relationship between aerobic fitness level and time to increase rectal temperature 0.5° C from its pre-exercise value whilst working at two varying preliminary exercise intensities and to observe if relative or absolute work is the primary determinant for this increase.

18 healthy male physical education students were first given a Sjostrand PWC_{170} test from which workloads corresponding to a PWC_{135} heart rate (T135) and PWC_{165} heart rate (T165) were calculated. All subjects completed both preliminary exercise conditions and a control condition prior to both the speed and endurance task. An 0.5° C increase in rectal temperature from its pre-exercise value indicated that a preliminary exercise state had been achieved.

The T135 preliminary exercise condition proved significantly ($p<.05$) superior on both the speed and endurance tasks. The results seem to indicate that resistance and not the intensity of work is the key factor.

The low fitness group (N=7) took significantly ($p<.05$) longer to increase their rectal temperature 0.5° C under both the T135 and T165 conditions. The results imply that knowledge of aerobic fitness level may only add minimally to the predictability of the time to increase

rectal temperature.

When working at 50% $\dot{V}O_2$ max. (T135) for approximately 15 minutes it seems that the relative workload for each individual is more important than the absolute workload in achieving the 0.5° C temperature increase.

It appears a directly related preliminary exercise at an intensity approximating 50% $\dot{V}O_2$ max. (T135) for approximately 15 minutes can enhance a speed performance (approx. 10 secs.) and endurance performance (approx. 4 mins.) on the bicycle ergometer.

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INTRODUCTION

> In regard to whole-body warm-up and large-muscle activity, there seems little doubt that any procedure that increases rectal and muscle temperatures will improve subsequent athletic performance. (24:375)

Statements similar to the above can be readily located in almost any text on exercise physiology. However, the values of preliminary exercise have recently been questioned. Although still accepted by the majority of athletes today, and an integral part of their athletic repertoire, some studies have cast doubt upon the real value of preliminary exercise and have consequently made it a worthwhile research topic (21:11, 41:300, 54:446, 76:1069, 92:147).

The most basic claims of preliminary exercise are that it will improve performance and aid in injury prevention, and those of us with any background in athletics would most likely support these general assumptions. There would seem little doubt that preliminary exercise plays some role in physical performance, whether it be reflected in improved performance, injury reduction, psychological readiness, physiological changes or combinations of one, or all, of these factors. Of the non-empirical evidence available there appears total agreement on the values of preliminary exercise and the majority of the experimental data suggests the same conclusions. An integral part of the educational process is, however, to question accepted concepts and for this reason the concept of preliminary exercise deserves further attention.

The empirical data available indicates that preliminary exercise is either beneficial (1:1, 7:45, 72:55, 104:231), has no significant effect (36:246, 40:1117, 53:63, 87:45), or actually produces detrimental results (21:11, 32:19, 41:300, 87:45). Following a critical analysis of the majority of evidence available the importance of specificity of preliminary exercise emerges. In many of the studies where the researchers reported a zero or negative effect from preliminary exercise the type of preliminary activity adopted was questionable, as was the combination of work intensity and duration. Presuming each athlete, or coach, has a thorough understanding of the principles of the activity to be pursued then it appears each individual performer should carefully select the type, intensity and duration of preliminary exercise most suitable for themselves and for the performance.

Although a considerable amount of research has been done in this general area, the studies have been extremely varied in type, intensity and duration of preliminary exercise as well as in the criterion test on which the preliminary exercise effect has been measured. The aim of this study was to examine the effect of using a directly related preliminary exercise on two criterion tests - one being a speed task on the bicycle ergometer and the other an endurance task. Apart from the control group, there were two treatment groups using varied preliminary exercise intensities as determined by a physical work capacity heart rate of 135 and 165 beats per minute. All preliminary exercise was completed on the bicycle ergometer. The indicator of sufficient preliminary activity was a stipulated increase in deep body temperature (0.5°C).

It was hoped that by using an experimental structure like the one outlined that we could supply some answers to several, or all, of the following questions:

1. Did the speed and endurance task times significantly differ between the control groups and the treatment groups following the

directly related preliminary exercise?

2. Were there any differences in the effect of the preliminary exercise when physical fitness was taken into account?

3. Was there an optimal preliminary exercise work intensity?

4. Was the time to increase the rectal temperature determined by the relative or absolute work output?

5. Was the time to increase the rectal temperature related to the subject's aerobic fitness level?

6. Was the adopted increase in deep body temperature sufficient for the criterion task?

7. When working at higher intensities did fatigue play a part? Was the control successful and necessary?

8. Was the psychological control successful?

9. Were any injuries incurred during the control condition?

To attempt to answer questions like those outlined above the research project must be very carefully designed and conducted. Some studies in the past have been criticized for their choice of dependent and independent variables and their poor scientific control, yet influential and consequently inaccurate conclusions have been drawn. The ultimate effect of this type of data is reflected in the confusing picture one receives from reviewing the literature on preliminary exercise. It was hoped that this study was so constructed, with clear and relevant dependent and independent variables, associated with sound scientific control that the results would, in some small way, help clear the air in regard to our knowledge of preliminary exercise and physical performance utilizing speed and endurance tasks on the bicycle ergometer.

Definition of Terms

Deep body temperature: refers to the internal temperature of the body as measured by a rectal thermistor to a depth of 10 centimeters.

Directly related preliminary exercise: refers to any preparation that involves movements identical to those being used in the performance criterion. Also referred to as formal preliminary exercise.

Endurance performance: refers to any prolonged work that requires a regular supply of oxygen and substrates for its completion (aerobic).

Indirectly related preliminary exercise: refers to any preparation that involves movements similar to those being used in the performance criterion.

Passive preliminary exercise: refers to any preparation in which the subject exerts no effort and applies no external force. Hot showers, short-wave diathermy are classified in this category.

Preliminary exercise: refers to any preparation that is undertaken prior to physical exercise for the purpose of producing optimal work performance; it is hoped that it will activate the necessary systems of the body and produce a condition of physiological and psychological readiness in the participant. If an active preliminary exercise it should be at the non-fatiguing level, but should be an exercise of sufficient intensity to place the individual under moderate to relatively heavy stress. For the purposes of this study the indication that the preliminary exercise criterion had been achieved was a stipulated increase in deep body temperature (0.5° C).

Psychological effect: refers to a mental preparation within the individual which may result in an improvement in performance.

Speed Performance: refers to any work that can be completed in such time as to require only high energy stores for metabolic fuel i.e. ATP, CP, for its completion (anaerobic).

Unrelated preliminary exercise: refers to any preparation that does not include solely the muscle area to be used in the performance criterion. General calisthenics are classified in this category. Also referred to as informal preliminary exercise.

METHODOLOGY

Subjects

18 male students aged 21 to 41 years from the Faculty of Physical Education at the University of Alberta volunteered for this study. Relevant anthropometric and physiological measures are shown in Table 1. Subjects were tested during a 6 week period from February 16th. to March 26th., 1975 and where possible at the same time each week. In an attempt to eliminate any possible psychological preparation prior to each testing session all subjects were kept naive as to the true nature of the experiment.

Apparatus

Equipment used for the research included:

1. Monark bicycle ergometer equipped with an electric metronome and independent revolution counter (Marietta).
2. Sanborn 500 electrocardiograph (E.C.G.).
3. Yellow Springs telethermometer in series with a Sargent recorder (Model SRG).
4. Thermistor with 10 centimeter catheter of semi-rigid construction as described in review of literature.
5. Gra-lab electronic timer (Model 171).

TABLE 1

INDIVIDUAL ANTHROPOMETRIC AND PHYSIOLOGICAL MEASUREMENTS

SUB.	AGE (YRS.)	HT. (INS.)	WT. (KG.)	PWC 170/ KG.	PRED. VO_2 MAX. (ML/ KG/MIN.)	T135 TIME ↑ Tr (MINS.)	T165 TIME ↑ Tr (MINS.)	FITNESS GP.
1	25.6	74.5	88.2	15.51	42.69	14.83	16.38	L
2	32.4	69.3	68.6	17.35	43.83	12.77	10.99	0
3	25.6	69.3	73.9	19.50	56.07	13.76	9.22	H
4	25.9	69.5	82.5	15.32	39.56	21.35	17.74	L
5	22.6	68.0	70.7	16.56	48.23	19.21	10.68	0
6	22.2	70.8	89.2	9.98	28.93	22.33	17.85	L
7	22.3	68.3	58.3	15.89	49.50	17.35	21.20	0
8	27.6	68.5	78.0	15.28	42.09	10.76	9.07	L
9	41.3	70.8	75.9	14.48	35.83	15.09	18.61	L
10	23.9	69.0	68.9	14.44	44.23	18.00	13.24	L
11	22.8	71.0	73.6	18.35	53.01	17.55	15.13	H
12	21.0	69.8	73.1	19.59	56.24	11.30	8.45	H
13	24.7	69.0	76.4	18.03	51.92	13.42	9.46	H
14	22.5	70.0	81.6	22.84	61.07	12.06	8.09	H
15	22.8	69.0	76.3	14.66	43.32	14.99	13.49	L
16	28.4	65.5	72.0	18.38	48.16	10.10	10.25	H
17	26.8	70.0	75.9	15.57	46.25	13.43	11.18	0
18	23.5	74.0	82.9	19.18	54.02	16.03	12.39	H
Mean	25.7	69.8	75.9	16.72	46.94	15.24	12.97	
S.D.	4.7	2.0	7.2	2.73	7.89	3.40	3.86	

L = Low

0 = Not Included

H = High

6. Hanhart DGM 1902 490 stopwatch.

Laboratory Protocol

Ambient temperature was maintained between 20 and 22° C with the relative humidity between 45 and 65%. All subjects wore running shoes and shorts, with no T-shirt, for all experimental conditions. The same instructions were given to all subjects regarding the criterion tasks and all were instructed identically regarding the preliminary exercise conditions. Subjects rested in a sitting position for 5 minutes on entering the laboratory during which time pre-exercise rectal temperature and heart rate was telemetered. In the control situation subjects rested an additional 10 minutes prior to completing the criterion tasks. After completing all preliminary exercise conditions subjects rested for 2 minutes prior to performing the associated criterion task.

At the conclusion of all the testing each subject was questioned regarding the purpose of the experiment. Their responses were used to indicate effectiveness of the psychological control applied throughout the testing sessions.

Selection of Preliminary Exercise Workloads

All subjects initially completed the Sjostrand Physical Work Capacity Test (PWC_{170}). From these results workloads corresponding to heart rates of 135 and 165 beats per minute (b.p.m.) were extrapolated. These workloads will be referred to as PWC_{135} and PWC_{165} and constitute the intensity of work performed as preliminary exercise in the T135 and T165 treatment conditions respectively.

An appropriate program was designed for the APL 360/67 computer which calculated the required PWC_{135} (T135) and PWC_{165} (T165) workloads using the principle of simple regression (Appendix B). The same program calculated PWC $_{170}$, PWC $_{170}$/kilogram, predicted maximal oxygen consumption (VO_2 max.) both in liters/minute and milliliters/kilogram/minute. Where applicable an age correction factor was automatically applied. As indicated by both Astrand et al. (4:354) and an earlier pilot study a 50% VO_2 max. workload is indicated by a heart rate of approximately 135 b.p.m. A heart rate of 165 b.p.m. is an approximation of a 75% workload. For this reason the PWC $_{135}$ and PWC $_{165}$ extrapolated workloads were utilized.

For the initial PWC $_{170}$ evaluation the subject pedalled continuously for 12 minutes at 60 revolutions per minute. The number of revolutions were recorded at the end of each 4 minutes of exercise. The workloads were adjusted to achieve a heart rate of 120 to 130 b.p.m. by the end of the first 4 minutes, 140 to 150 b.p.m. by the end of the 8th. minute and 165 to 175 b.p.m. by the end of 12 minutes. The actual work output for the 4th., 8th. and 12th. minutes was computed by multiplying the mean workload for each 4 minute period by the number of pedal revolutions for the same period and this total by 6, the distance in meters of one revolution. Within the APL 360/67 program the appropriate PWC $_{135}$ (T135) and PWC $_{165}$ (T165) workloads were calculated. The resistance required for the PWC $_{135}$ workload was the resistance utilized for both the speed and endurance tasks.

<u>The Preliminary Exercise Criterion</u>

A criterion increase in deep body temperature, as measured rectally (Tr), was set at 0.5° C. All preliminary exercise was conducted on the bicycle ergometer. Used as a directly related preliminary exercise subjects pedalled at 60 revolutions per minute at their precalculated PWC $_{135}$ and PWC $_{165}$ resistance. Subjects continued working until their rectal temperature had risen 0.5° C from its pre-exercise value and the time elapsed for the increase was recorded. The rectal temperature was measured using a thermistor to a depth of 10 centimeters. A catheter of semi-rigid construction was used to ensure that on insertion it adopted an anterior position in the rectum hence avoiding the cooling effects from the returning venous blood (55:97). The temperature was recorded using the Yellow Springs telethermometer in series with the Sargent recorder. Both devices were calibrated to 37° C prior to each experimental session. The accuracy and effectiveness of this equipment was tested in a pilot study conducted earlier.

The pre-exercise rectal temperature was determined while resting in a seated position on the bicycle ergometer.

When completing the PWC $_{135}$ preliminary exercise resistance all subjects performed without rest. At the PWC $_{165}$ preliminary exercise resistance an interval type exercise was adopted to eliminate possible fatigue effects. Subjects worked for 3 minutes and rested for 1 minute until their rectal temperature had risen 0.5° C from its pre-exercise value.

The Performance Tasks

The PWC $_{135}$ resistance was adopted as the resistance for both performance tasks. These tasks consisted of a speed-type and endurance-type activity on the Monark bicycle ergometer. Specifically, the ergometer speed task involved the completion of 35 revolutions on the bicycle ergometer at the PWC $_{135}$ resistance. The same number of revolutions (35) and relative resistance was adopted for all subjects. The bicycle ergometer endurance task involved 350 revolutions also at the PWC $_{135}$ resistance for all subjects. The time taken to complete both tasks was recorded and heart rate was telemetered prior to and at the completion of the exercise.

Experimental Design

A repeated measures design was utilized; each subject acted as their own control and completed both a speed and an endurance task with and without two different types of preliminary exercise. That is, prior to a speed or an endurance task each subject experienced either no preliminary exercise or a PWC $_{135}$ or a PWC $_{165}$ resistance as a preliminary exercise until a criterion increase in rectal temperature of 0.5° C was achieved. This resulted in six different testing sessions for each subject, i.e. no preliminary exercise, preliminary exercise at PWC $_{135}$ and preliminary exercise at PWC $_{165}$ prior to both the speed and endurance tasks. Thus the three independent variables were:

1. No preliminary exercise (control).
2. Preliminary exercise at PWC $_{135}$ (T135).
3. Preliminary exercise at PWC $_{165}$ (T165).

The T135 and T165 conditions acted as directly related forms of preliminary exercise.

Following the completion of an initial PWC $_{170}$ test the subjects were randomly assigned to a number from 1 to 18 which determined, through utilizing a modified Latin Square, the order in which each subject performed the independent and dependent variables (Appendix C).

The dependent variables measured were:

1. Times to complete the speed-type (seconds) and endurance type (minutes) performance on the bicycle ergometer working at the same relative resistance.

2. Time to achieve the criterion increase in rectal temperature

(minutes).

The repeated measures design, associated with random assignment to order of performing each condition, resulted in greater internal validity and any "history effect" was consequently accounted for. To control for any testing effect was a greater problem as it is difficult to know if any change recorded in the performance times on the criterion tasks were due to the increase in deep body temperature or other unknown, yet inbuilt, factors.

The statistical analyses of the results involved both a one way and two way analysis of variance, both with repeated measures. The statistical computations were made using an ANOVA15 (25) and ANOVA23 (25) computerized program.

To determine the effect of the different treatment conditions on the two criterion tasks the one way analysis of variance with repeated measures (ANOVA15) was utilized. The two way analysis of variance (ANOVA23) was also applied with order of taking the test as the second factor. If a significant F-ratio was found the Newman-Keuls multiple comparison method using the studentized range was applied to determine which means were significantly different.

By examination of the PWC_{170}/kgm. and predicted VO_2 max. values high and low fitness groups were formed. Through the use of the two way analysis of variance with repeated measures program the effect of physical fitness on time to increase rectal temperature was examined. Each fitness group consisted of 7 subjects (N=14) allowing a clear division between the groups.

To determine if any relationship exists between individual fitness levels and time to increase rectal temperature a Pearson product moment correlation coefficient (r) was computed between both the PWC $_{170}$/kgm scores and predicted VO_2 max. values and the times to increase rectal temperature during the T135 and T165 conditions for the total group.

For this study the significant levels were set at $p<.05$ for all statistical analyses.

RESULTS

When performing the speed criterion task only the T135 preliminary exercise condition produced significantly ($p<.01$) improved performance over the control condition. It also produced a significantly ($p<.05$) better speed performance in comparison to the T165 condition (Figure 1).

When performing the endurance criterion task, once again only the T135 preliminary exercise condition produced significantly ($p<.05$) improved performance over the control condition and again also produced a significantly ($p<.05$) improved endurance performance in comparison to the T165 condition (Figure 2).

The mean times to increase the rectal temperature 0.5° C from its pre-exercise value were 15.24 (±3.41) minutes for the T135 preliminary exercise condition and 12.97 (±3.86) minutes for the T165 preliminary exercise condition (Figure 3). These times were significantly different ($p<.001$).

In order to ascertain any relationship between an individuals fitness level and their time to increase rectal temperature 0.5° C from the the pre-exercise value, when exercising under the T135 and T165 conditions, correlations between these times and each subjects PWC $_{170}$/kgm. score and predicted VO_2 max. (ml/kgm/min.) value were computed.

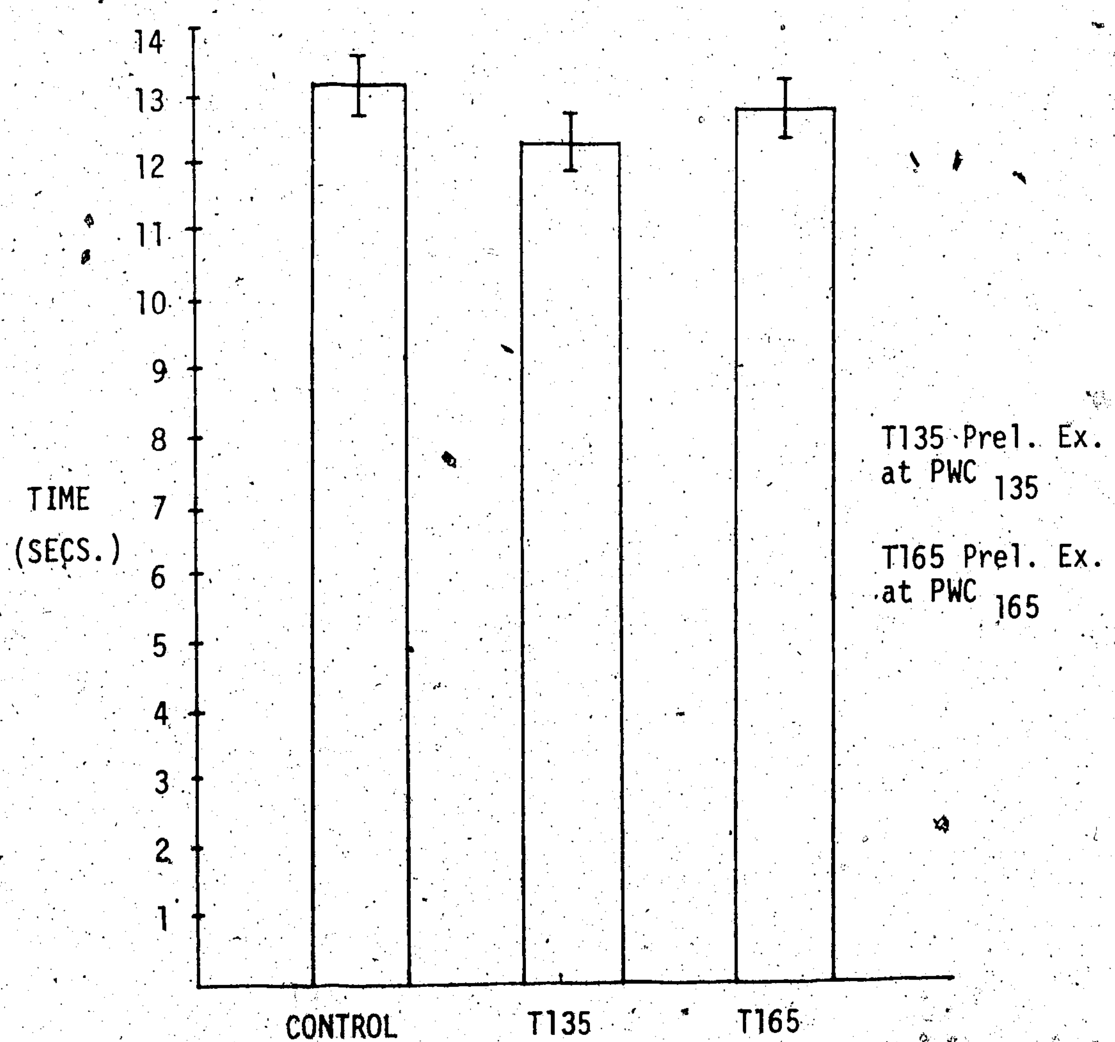

FIGURE 1: The Effect of Two Different Intensities of Preliminary Exercise on the Performance of a Speed Task.
*significantly different from both control ($p<.01$) and T165 ($p<.05$)

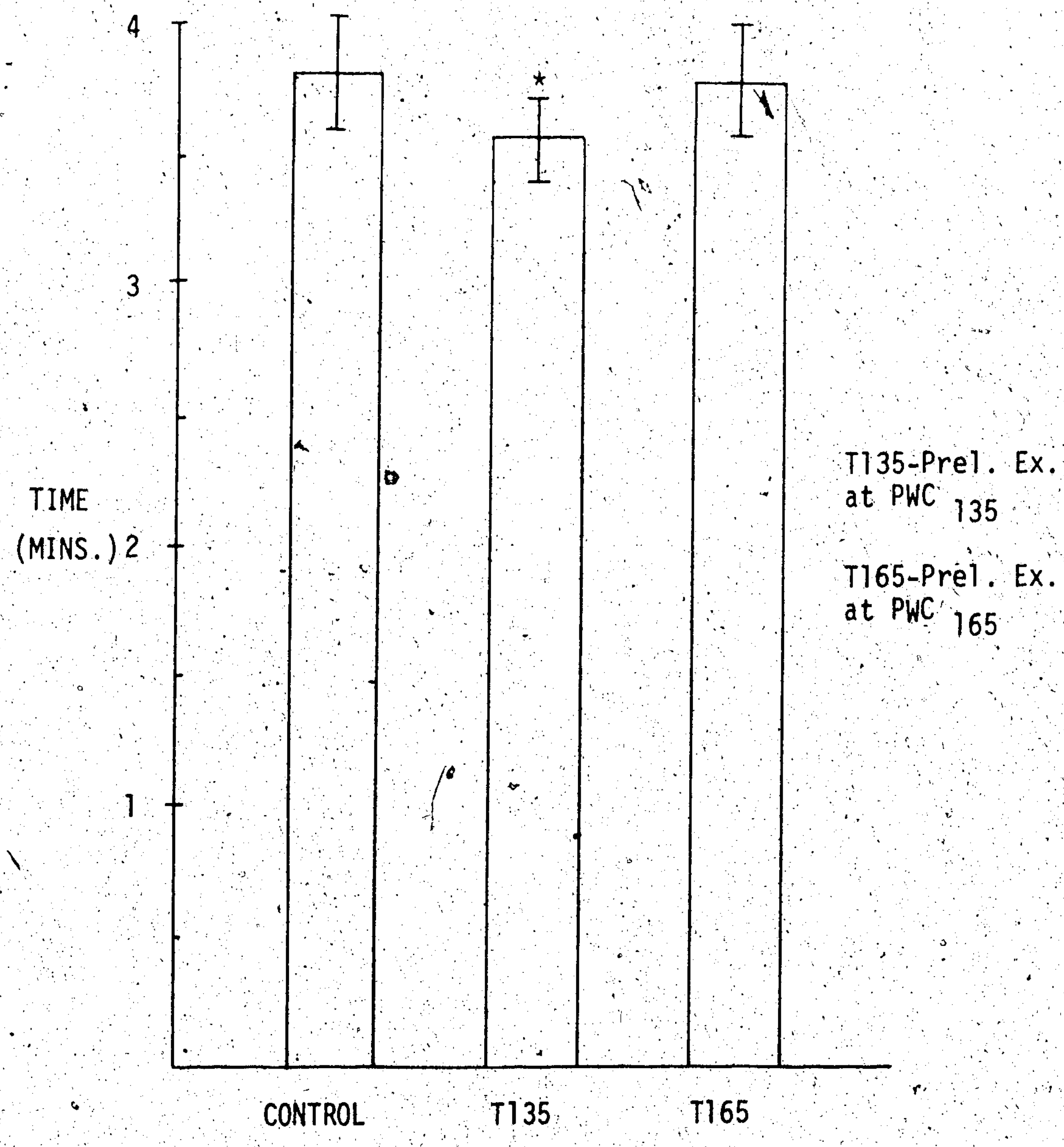

FIGURE 2: The Effect of Two Different Intensities of Preliminary Exercise on the Performance of an Endurance Task.
*significantly different from control and T165 ($p<.05$).

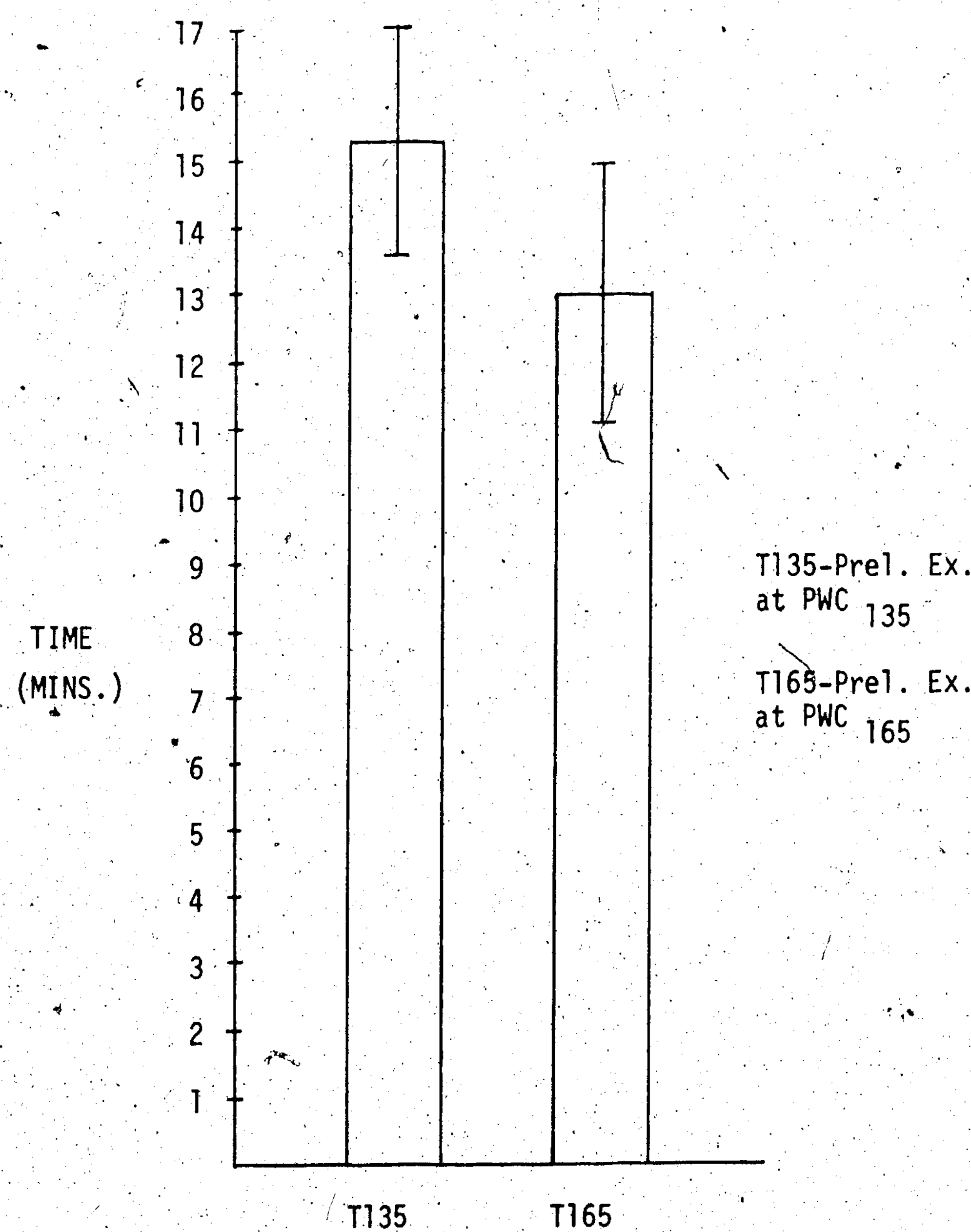

FIGURE 3: The Effect of Two Different Intensities of Preliminary Exercise on Time to Increase Rectal Temperature 0.5° C From its Pre-Exercise Value.
Times significantly different ($p<.001$)

Correlations between the times to increase rectal temperature under the T135 and T165 conditions and the PWC $_{170}$/kgm. value were -0.578 ($p<.02$) and -0.623 ($p<.01$). When making the same comparisons but using the predicted $\dot{V}O_2$ max. values in ml/kgm/min. correlations of -0.478 ($p<.05$) and -0.59 ($p<.02$) were found.

After allocating 7 subjects to each of a high and low fitness group it was found that under both the T135 and T165 conditions the high fitness group achieved the required increase in rectal temperature within a shorter time ($p<.05$) (Figure 4).

The PWC $_{170}$/kgm. scores ranged from 9.98 to 22.84 with associated T135 workloads of 450 and 930 kpm. and T165 workloads of 720 and 1470 kpm. The predicted $\dot{V}O_2$ max. values ranged from 28.93 to 61.07 ml.kgm/min. When exercising under the T135 preliminary exercise condition the range in times for the total group (N=18) to increase their rectal temperature was 10.10 to 22.33 minutes and under the T165 condition from 8.09 to 21.20 minutes. Complete data is recorded in Table 1.

In statistically analyzing the data pertaining to the criterion performance tasks the use of the two way analysis of variance with repeated measures (ANOVA23) did not yield a more significant F-ratio in either case so the ANOVA15 one way analysis of variance with repeated data was reported (Appendices C and D).

The psychological control attempted proved ineffective in all but 6 subjects.

No injuries were reported throughout the entire testing session.

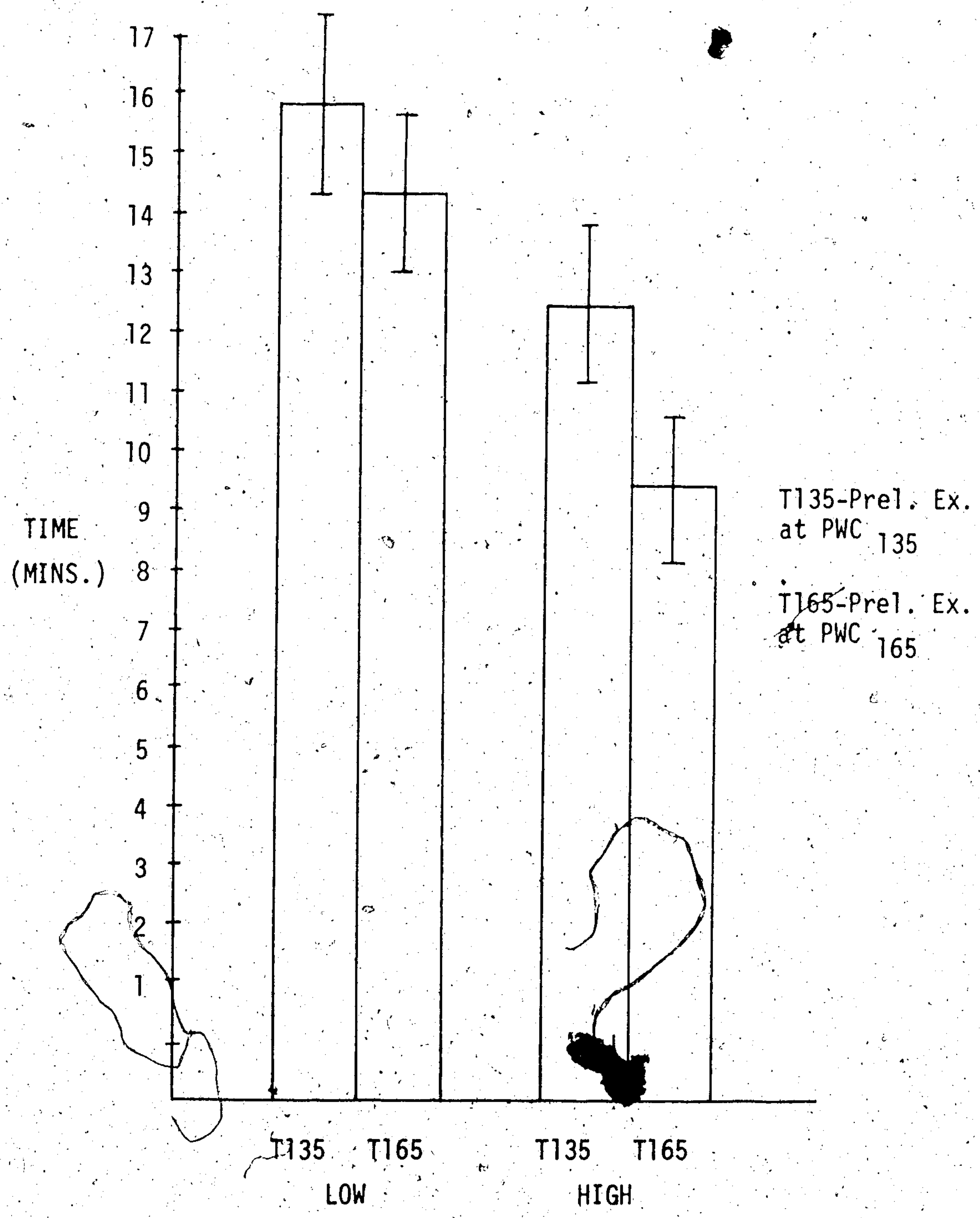

FIGURE 4: The Effect of Fitness Level on Time to Increase Rectal Temperature 0.5° C From its Pre-Exercise Value When Working at Two Different Intensities.
Low fitness times, at same intensity, significantly different from high fitness times ($p<.05$)

DISCUSSION

Direct comparisons with other studies in this area are difficult to make since the preliminary exercise workload, the specific criterion tasks and the technique for determining if a preliminary exercise condition had been achieved are, in total, unique to this study. Only the use of the bicycle ergometer for both the preliminary exercise and the criterion task reflect similar procedures adopted in other studies.

The faster times recorded in the speed criterion task following both the T135 and T165 preliminary exercise conditions basically support the results found by Asmussen et al. (1:1) and Schmid (85:950). The T135 preliminary exercise condition produced the only significant time decrease (Figure 1), being significantly faster than both the control ($p<.01$) and T165 ($p<.05$) condition. It appears that a preliminary exercise workload approximating a physical work capacity heart rate of 135 beats per minute (b.p.m.) produces an optimal performance, within this experimental environment, on a task involving a maximal speed performance on the ergometer of 35 revolutions at the same resistance. One explanation may be that different muscle pools were recruited for the preliminary exercise (slow twitch oxidative) than the criterion task (fast twitch glycolytic).

When pedalling at 60 revolutions per minute on the bicycle ergometer at the T135 resistance the mean time (15.24±3.41 mins.) for all subjects (N=18) to increase their rectal temperature 0.5° C from its pre-exercise value was similar to that reported by other investigators (16:131, 84:1757). Presuming it is some augmentation of physiological parameters (Appendix A) that is responsible for the improvement in speed performance which was found, then a 15 minute preliminary exercise time at the T135 resistance should allow sufficient time for these physiological adaptations to occur. This T135 resistance corresponds to a workload approximating 50% of the subject's VO_2 max. (4:354). The associated increases in rectal temperature and heart rate at this workload are the only physiological adaptations that can be empirically supported from this study.

Several investigators have found an improvement in endurance performance on the bicycle ergometer following a directly related preliminary exercise (1:1, 9:138, 101). In comparison to the control group, faster endurance times were found following both the T135 and T165 preliminary exercise condition although only the T135 condition produced a significant ($p<.05$) decrease. This time was also significantly ($p<.05$) faster than the T165 condition. This would indicate that a preliminary exercise workload approximating a physical work capacity heart rate of 135 b.p.m. produces an optimal performance, within this experimental environment, on a task involving a maximal performance of 350 revolutions at the T135 resistance. As with the speed criterion task the mean time (12.97±3.86 mins.) to increase the rectal temperature would allow a majority of the necessary physiological adaptations to be made.

The specificity of preliminary exercise cannot be overemphasized. Within this study the preliminary exercise workloads were completed at a resistance corresponding to a PWC_{135} or PWC_{165} value, depending on the condition. The PWC_{135} (T135) resistance was maintained for both the speed and endurance criterion tasks whether they followed the control, T135 or T165 condition. The fastest times for both the speed and endurance tasks were found following this T135 condition, lending support to the principles of specificity of resistance, but not of intensity, as the lower intensity (T135) preliminary exercise was always superior.

Following this specificity discussion to its logical conclusion one would expect to find the greatest improvement in performance in the endurance task as the mean pedal rate was 94 revolutions per minute, a rate which more closely resembled both preliminary exercise conditions (60 r.p.m.). In the speed task the mean pedal rate was 165 revolutions per minute. But this was not the case as the greatest improvements in performance were found within the speed task (Table 2). It would therefore seem that resistance and not speed or intensity is more important in determining improved performance.

Although the speed and endurance performance times were not significantly faster following the T165 preliminary exercise conditions some improvement over the control was noted (Table 2). Approximating a 75% VO_2 max. workload (4:354) this resistance proved too severe for the subjects in the preliminary testing to maintain continuously for a sufficient time to increase their rectal temperature 0.5° C. Consequently the intermittent rather than the continuous schedule was adopted. Even after assuming a 3 minute exercise, 1 minute rest schedule it appeared that this preliminary exercise intensity was still too severe. The mean heart rate for all subjects following the T165 conditions was 162±15 b.p.m. whereas the T135 preliminary exercise conditions produced a mean heart rate of 142±8 b.p.m. The mean time to increase the rectal temperature during the T165 condition was significantly ($p<.001$) less at 12.97±3.86 minutes and it is possible that this work period, as reflected in the time for the associated increase in temperature, was less effective in mobilizing the previously mentioned physiological parameters.

TABLE 2

COMPARISONS BETWEEN MEAN SPEED AND ENDURANCE PERFORMANCE TIMES ON

ALL 3 CONDITIONS.

	CONTROL	T135	T165	DIFF. C/T135	% IMPROV'T	DIFF. C/T165	% IMPROV'T	DIFF. T135/T165	% IMPROV'T
SPEED (secs.)	13.12	12.26	12.75	0.86	6.6	0.37	2.8	0.49	3.9
ENDURANCE (mins.)	3.81	3.58	3.79	0.23	6.1	0.02	0.5	0.21	5.7

The T165 condition could have shown greater improvement in performance if the work intervals had been shortened to decrease the effect of fatigue e.g. 60 seconds work with 30 seconds rest. It does appear that these intervals were too long in this research.

Although the endurance task following the T165 condition recorded a mean performance time of only 3.79±.46 minutes, compared with the control time of 3.81±.45 minutes, it is possible that the early portion of this activity itself may have produced some within-task enhancement which would have masked some positive effect from the preliminary exercise. But one would have expected the same occurrence with the endurance task following the T135 condition and this was not the case. Still, within-task enhancement is a worthy consideration.

The proximity of the post-preliminary exercise heart rates to those obtained from the physical work capacity test at the same resistance should be noted. Following the T135 condition (PWC_{135}) a mean heart rate of 142±8 b.p.m. was telemetered and following the T165 condition (PWC_{165}) one of 162±15 b.p.m. The accuracy of the latter recording is questionable since it was possible for this reading to be taken during the latter part of the rest period on the intermittent exercise schedule. But this does indicate that the actual preliminary workloads were very close to those desired.

Within the limitations of this study there appears to be an optimal preliminary exercise workload and within this workload it seems the resistance and not the intensity is most relevant. A workload corresponding to a physical work capacity heart rate of 135 b.p.m., or approximately 50% $\dot{V}O_2$ max., produced the most favourable results in both criterion tasks. An associated mean exercise time of 15.24±3.41

minutes was recorded, being the time to raise the rectal temperature, 0.5° C at the T135 resistance and 60 pedal revolutions per minute.

It would also appear from this study that a workload corresponding to a physical work capacity heart rate of 165 b.p.m., or approximately 75% $\dot{V}O_2$ max., when adopted under an intermittent exercise schedule tended to result in superior performance times than no preliminary exercise ($p<.10$).

The evidence from this particular research supports the utilization of preliminary exercise but as previously noted the acceptance of this principle is far from conclusive. It seems there is no single factor accounting for this improvement in performance. An undetermined combination of physiological (Appendix A) and possibly psychological readiness factors associated with some learning/practice effect seem to play the most dominant role.

All the physiological factors listed could have come into play and an attempt was made to maintain psychological control by keeping all subjects naive as to the true nature of the research. Although this method has supposedly been successfully adopted by other researchers in the area (1:1, 9:138, 71:202) it was found to be generally ineffective in this study. Many of the subjects were aware of the researcher's area of interest and were able to recognize the true purpose of the study by simple examination of the experimental procedures. In only 6 subjects (N=18) was any true psychological control maintained. This failure to eliminate the mental readiness factor within 12 subjects makes it even more difficult to delineate the most relevant reasons for improved performance. As one researcher found (53:63) this mental preparation is possibly the most important single factor in producing optimal performance.

By adopting a Latin Square design to determine the order in which subjects completed each preliminary exercise condition and associated criterion task had the desired effect in eliminating an overall learning or practice effect. Without the utilization of this design principle the results from the speed tasks would most likely be unchanged but the learning effect from the endurance task would have been considerable. All subjects reported a marked learning effect related to the pedalling rate for the endurance criterion task. The effect of this learning was eliminated through the adopted experimental design. By randomly assigning subjects to a position from 1 to 18 and by assuming the Latin Square design individual variation in learning, and any test-to-test learning that may have occurred, was accounted for.

Since physical education students with pre-determined ideas regarding preliminary exercise were used throughout, it is possible they were unwilling to perform to their maximum during the control phase of the experiment. During the testing 7 subjects requested preliminary activity prior to the completion of the control performance tasks. This may partially account for the improvement in performance when comparing the T135 and T165 condition times to the control times, but would play no part in the improved T135 times over those of the T165 condition. It is possible that subjects and athletes unconsciously control their initial activity level to enable the early portion of the performance task to act as a preliminary exercise period.

One of the problems expected with the T165 preliminary exercise condition, if completed as a continuous exercise, was fatigue. As previously mentioned, prior to the actual testing period 3 subjects were worked at the T165 condition until they raised their rectal temperature 0.5° C from the pre-exercise value - 2 of the subjects were unable to complete the exercise. An intermittent type exercise was then adopted and no further fatigue problems were evident. Although this change from continuous to intermittent exercise eliminated the obvious fatigue factors this preliminary exercise was still possibly too severe for the selected criterion tasks and this would account for the reduced effectiveness of the T165 preliminary condition.

Prior to initiating this research a pilot study was conducted with 16 male physical education students (20 to 40 years) to determine the effect of physical exercise on deep body temperature when aerobic fitness level of the subjects was taken into account. Although the more fit subjects performed the same relative workload as the less fit they were working at a higher absolute workload and consequently expended more energy and hence generated more metabolic heat. It was thought this would result in a decreased work time to achieve an 0.5° C rise in rectal temperature when the fit subjects worked at the relative workload. This deep body temperature, as measured rectally, and probably the temperature in the working muscle, has been shown to be a function of the relative workload of the individual and not the absolute workload performed (2:64, 68:120, 84:1757). This evidence suggests that subjects working at similar relative workloads, as set by a percentage of $\dot{V}O_2$ max., or workloads corresponding to specific heart rates from a Physical Work Capacity Test (PWC_{170}), will not show a significantly different deep body temperature (Tr) following an identical work time of 1 hour or more.

The pilot study results indicated that whilst working at a relative workload approximating 50% of the subjects $\dot{V}O_2$ max. there was no significant difference in the time for the subjects to increase their rectal temperature 0.5° C from the pre-exercise value. A correlation of r = -0.11 was obtained in computing the relationship between $\dot{V}O_2$ max. (ml/kg/min.) and time to increase rectal temperature (minutes). The variation in maximal oxygen consumption was from 45.80 to 67.70 ml/kg/min. with subsequent 50% workloads of 750 and 900 kpm. and rectal temperature increase times of 19.58 and 18.68 minutes respectively. The mean time for the temperature increase was 18.18±3.54 minutes.

In first considering the T135 condition, which approximates a 50% $\dot{V}O_2$ max. workload a mild trend is recognizable from the correlation of r = -0.48 when predicted $\dot{V}O_2$ max. (ml/kg/min.) is correlated with time to increase rectal temperature. This trend was further supported when fitness level, used as one factor in a two way analysis of variance, showed a significant ($p < .05$) main effect. Both these results indicate that aerobic fitness level should not be ignored when time to increase deep body temperature whilst working at the same relative workload is being considered. This result then is somewhat in conflict with the pilot study and possibly with the work of several other investigators (2:64, 66:815, 84:1757) who conclude that during performance at a relative workload of 50% $\dot{V}O_2$ max. there appears no significant difference between fitness levels and time to increase rectal temperature. This conclusion is drawn from the fact that at a lower relative workload (50% $\dot{V}O_2$ max.) temperatures stabilize at a similar level in both the high and low fitness groups even though the high group makes a greater effort in relation to energy consumption and hence during their work period more heat is produced per unit time. Since no stabilization occurred in either study this assumption may be questionable although our preliminary exercise was only about 15 minutes in duration. It therefore is difficult to draw comparisons with these other studies since all their work times were greater than 30 minutes.

The deviation of this T135 condition result from the previous study is not so severe as to eliminate the fact that a relationship between the relative intensity of the work performed and an individual's deep body temperature does exist. Whilst working at approximately 50% $\dot{V}O_2$ max. an increase in the amount of metabolic heat produced results in a rise of the deep body temperature and a consequent deviation from the bodies set-point. This in turn activates the bodies heat dissipation mechanisms and causes increased skin blood flow and sweat excretion (46: 815). The removal of excess heat via these mechanisms is insufficient as the lowered skin temperature, due to sweat evaporation, reduces the blood flow and the sweat gland activity and the deep body temperature (Tr) increases. It may stabilize at a new level corresponding to a balance between the activating stimuli and those concerned with continued cooling (46:815). This reaction of the bodies heat dissipation mechanisms does appear to be related to relative and not absolute workload within the individual when working at 50% $\dot{V}O_2$ max. or less and for periods of time in excess of 30 minutes. This relative workload expresses a ratio between the individuals demand for oxygen and his elimination of excess heat and at 50% it is expected that there will be little difference in the time for any individual to increase their rectal temperature 0.5° C (2:64, 84:1757). But it is possible that the absolute work done does play a more significant role in some individuals. The relative homogeneity of the sample used may have made it difficult to draw these conclusions.

When correlations were made using the predicted $\dot{V}O_2$ max. values and times to increase the rectal temperature under the T165, or 75% $\dot{V}O_2$ max., preliminary exercise condition ($r = -0.59$) a similar trend as with T135 was found. The literature is less convincing in indicating the importance of relative workloads with these higher resistances but Saltin et al. (84:1757) found no significant difference in time to increase rectal temperature when working at about 70% $\dot{V}O_2$ max. for over 1 hour.

The shorter times to achieve the criterion increase by the subjects in the high fitness group could reflect a relative stabilization of the deep body temperature of these subjects. Although they may reach the criterion increase level earlier due to the greater amount of absolute work performed their heat dissipation mechanisms may handle this increase more efficiently and allow a lower stabilization to occur. Kozlowski (46:815) found that during 65% $\dot{V}O_2$ max. exercise subjects with higher relative workloads had stable rectal temperatures after 30 to 45 minutes whereas subjects working at the lower percentage $\dot{V}O_2$ max. levels rectal temperatures were 0.5° C greater after one hours work. In the present study it is unlikely that any serious stabilization could occur since the mean times to increase the rectal temperature under the T135 and T165 conditions were 15.24±3.41 minutes and 12.97±3.86 minutes respectively for the total group. By completing the same experimental procedure on the faster responding muscle temperature this hypothesis could more effectively be tested.

In considering the information from both the present study and the earlier pilot study it does appear that relative workload is a factor in determining the rate at which deep body temperature (Tr) increases, especially in the first 15 minutes, and that possibly an understanding of the aerobic fitness level of the subjects will only add minimally to the understanding of these principles. If fitness level is related it is likely that the relationship will be mildly negative and the fitter individuals, with the greater absolute workloads, will increase their temperatures more rapidly.

In line with almost all other studies completed in this area no injuries were reported in any of the experimental conditions. In particular no injuries were reported following the control condition. No patterns were recognizable from these reports. From this experimental situation it appears that injury prevention cannot be stated as a major value of preliminary exercise although one would not advise heavy physical exertion without it.

CONCLU[illegible]

From th[illegible] conducted in this study it seems the following conclusions can [illegible]ined;

1. [illegible]taking preliminary exercise at approximately 50% $\dot{V}O_2$ max. (PWC $_{135}$) [illegible]l deep body temperature rises 0.5° C, results in superior speed and [illegible]urance performance on a bicycle ergometer set at that same resistanc[illegible]

2. In increasing rectal temperature 0.5° C from its pre-exercise value working at a relative workload high aerobic fitness level subjects may achieve the criterion increase more rapidly. Hence, aerobic fitness level may give some indication as to the time individuals will take to increase their deep body temperature.

3. The type of preliminary exercise and not the criterion increase in deep body temperature (Tr) appears most crucial in achieving optimal value from preliminary exercise.

4. The resistance and not the speed or intensity of the preliminary exercise appears most relevant.

When applying these research conclusions to those already extracted from the review of literature the following points appear with some consistency:

1. The preliminary exercise workload should be sufficient to place the individual under moderate to heavy stress.

2. The preliminary exercise should be sufficient to raise both muscle and deep body temperature.

3. Long (up to 30 minutes), vigorous (40-60% VO_2 max.) preliminary exercises contribute more than short, moderate ones. One must be aware of fatigue factors in adopting heavier workloads, particularly with untrained subjects.

4. The rest period between preliminary exercise and criterion performance should be short, preferably no longer than 15 minutes.

5. There are undoubtedly important psychological and motivational aspects involved.

6. Preliminary exercise is thought to reduce susceptibility to muscle and joint injuries and increase flexibility/mobility to those joints.

When considering the total realm of preliminary exercise and performance several more general conclusions may add some clarity and coherence to the area:

1. Preliminary exercise is a necessary and important part of

almost every athlete's repertoire.

2. Directly related preliminary exercise should be adopted where possible, but indirectly related and unrelated preliminary exercise is better than no preliminary exercise for most individuals.

3. Preliminary exercise procedures must be suited to both the activity and the individual. For optimal effects there are optimal workloads and durations.

4. Age, sex, physical condition, skill level, attitude, motivation are all variables to be considered when allocating a preliminary exercise schedule.

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APPENDIX A

APPENDIX A

REVIEW OF LITERATURE

Reported studies in this area began in the 1930's and continued at a productive rate until the late 1960's from which time few have been published. Although there appears to be adequate evidence available in the area,few valid conclusions can be drawn since the conduct and structure of much of the research makes comparisons and conclusions meaningless. Given an appreciation for the specificity of preliminary exercise makes conclusions even more difficult to draw. What we can establish from the literature is some insight into the nature of preliminary exercise, the types of preparation undertaken, its duration and intensity and the varying performance criterion, all of which indicate its diversified and complex nature.

In attempting to present the information in a meaningful fashion I have reported the general, non-empirical view points first,and then provided an over-view of the empirical data, followed by a more specific examination of the anaerobic and aerobic performance areas as indicated by speed and endurance tests on the ergometer. Finally, a review of some of the work related to the measurement of rectal temperature.

After interviewing 33 champion U.S.A. athletes Miller (59:31) reported that 100% of these athletes engaged in serious preliminary exercise and all emphatically supported its value; both related and unrelated methods were adopted with a greater majority utilizing the former. Robson (81:27) reported total acceptance of preliminary exercise which varied in time from only a few minutes for marathon runners, to 1 hour. O'Connor (70:48) agrees that preliminary exercise is essential to the athlete and adds that a unique program for each athlete is nec[illegible] Finally, Warner (109:12) believes strongly in preliminary ex[illegible] cross country runners and states it should be extreme enough [illegible]he athlete to experience "second-wind" prior to the [illegible]forma[illegible]

In [illegible] emp[illegible] data available three areas of interest emerge - first, pr[illegible]min[illegible] exercise as related to physical performance; second, the psycho[illegible] aspects of preliminary exercise; and last, preliminary exercis[illegible] related to injury prevention. By far the greatest amount of wo[illegible] has been reported in the first area and in an attempt to present t[illegible] information in a meaningful and concise fashion Table was construct[illegible] The literature presented here covers the majority of work done du[illegible]ng the period 1936 to 1974. The limitations of this table are self evident,but it does outline the basic conclusions that have been drawn [illegible] the studies available as well as indicating the criterion test[illegible] preliminary activity used.

The brief appraisal of the information reported in Table 3 indicates there are 144 "units" of empirical evidence tabulated and 83 units (58%) state that the adopted preliminary exercise had some beneficial value, 51 units (35%) state that the preliminary exercise had neither a positive nor negative effect, and 10 units (7%) convey that the preliminary exercise had a deleterious effect on the criterion test. As can be seen the studies are extremely varied, both in the preliminary exercise procedure adopted and the criterion under which the preliminary exercise was tested. Although in some ways this could be levelled as a criticism it does give us some insight into the complexity of the general term "preliminary exercise."

TABLE 3

PRELIMINARY EXERCISE DATA SUMMARY

	FORMAL	INFORMAL			
	PRELIMINARY EXERCISE	EXERCISE	DIATHERMY	MASSAGE	HOT/COLD HYDROTHERAPY
RUNNING: **Speed:**	+Blank +Grodjinovsky ea,a +Hogberg ea +Malan +Schmid +Simonsen Ode Vries OHipple OIhm OMathews ea OPyke OSmith	+Grodjinovsky ea,a +Malan +Smith ea,b OBurke Ode Vries OHale OIhm OKarpovich ea OMathews ea OTremble	+Cheatum c	+Hale +Karpovich ea, d	+Hogberg ea,e +Sills ea OIhm ORosen OSmith
Endurance:	+Blohm +Grodjinovsky ea,a	+Blohm +Grodjinovsky ea,a OBurke			
ERGOMETER: **Speed:**	+Asmussen ea +Schmid OKarpovich ea OPyke OSkubic ea	+Schmid +Simonsen OKarpovich ea OMassey ea OSchutz OSkubic ea	+Asmussen ea +Schmid	+Schmid OAsmussen ea	+Asmussen ea +Schmid

TABLE 3 CONTINUED

	FORMAL	INFORMAL			
	PRELIMINARY EXERCISE	EXERCISE	DIATHERMY	MASSAGE	HOT/COLD HYDROTHERAPY
ERGOMETER cont: **Endurance:**	+Asmussen ea +Bonner +Sucec OStewart -Karpovich & Pestrecov		+Asmussen ea	OAsmussen ea	+Asmussen ea
SWIMMING: **Speed:**	+de Vries +Schmid +Thompson	+de Vries +Muido +Twardowski OThompson -de Vries	+Muido	+Schmid Ode Vries	+Carlile +de Vries +Muido +Schmid +Twardowski -Muido
Endurance:	+Thompson				
THROWING: **Accuracy:**	+Thompson OSinger ea OSkubic ea OStraub f	+Witte OSkubic ea OThompson			
Distance:	+Michael ea +Rochelle ea OPyke OSkubic	+Michael ea OSkubic ea			
Velocity:	+Van Huss f				

TABLE 3 CONTINUED

	FORMAL	INFORMAL			
	PRELIMINARY EXERCISE	EXERCISE	DIATHERMY	MASSAGE	HOT/COLD HYDROTHERAPY
STRENGTH: **Handgrip:**		+Harvill	+King ea,g	OGrose	+Clarke ea +Robbins OGrose -Clarke ea -Grose -Robbins
Back & Leg:	+Skubic ea	OGlidewell h	OGlidewell h		-Glidewell h
Elbow flexion:			-Sedgwick ea		
Knee flexion:		+Burke			
SPEED: **Arm:**	+Swegan ONelson ea,f	+Elbel +Paseltiner +Phillips OKing ea,i			
Rotary:	+Barch +Catalano ea	+Lotter OLotter			
Leg: **Reaction Time:**	+McGavin	+McGavin +Elbel j +King ea,j			+McGavin
JUMPING: **Vertical:**	+Stockholm ea,f OPyke	+Pacheco +Pacheco +Richards +Steacy +Van Grundy		+Merlino	

TABLE 3 CONTINUED

	FORMAL	INFORMAL			
	PRELIMINARY EXERCISE	EXERCISE	DIATHERMY	MASSAGE	HOT/COLD HYDROTHERAPY
ENDURANCE:					
Forearm Handgrip:	OSedgwick		OClarke ea OSedgwick ea	OGrose	-Grose
Arm Hold:			ONukada		ONukada
MISCELLANEOUS:					
Walking:					+Falls l
Flexibility:	+Fieldman +Lukes	+Fieldman +Lukes +Harvill			

a. Combination of formal/informal
b. Tested on obstacle race
c. Used ultraviolet radiation
d. Found positive effect later
e. Used sauna
f. Used overload warm-up
g. Thermocouples used
h. Leg strength and power
i. Used body movement
j. Body reaction time
k. Arm held at 90° to body with varying weights
l. Positive effect on circulatory response

The psychological aspects of preliminary exercise are now playing a more dominant role in the studies reported. Some of the studies attempt to control for any possible benefit in performance due to a psychological preparation as can be seen in Bonner's (9:138) recent study where he misinformed the subjects of the true nature of the experiment in order to control for any possible psychological/mental readiness influence. His approach proved effective as shown by the subject's surprise when informed of the true nature of the experiment. Rochelle et al. (82:499) in an experiment to determine the effect of preliminary exercise on throwing for distance attempted to rule out the possibility of a psychological effect of not making a maximum throw without preliminary exercise by giving a monetary reward for each throw greater than their previously established average. Like Bonner, Pacheco (71:202) attempted to control for possible psychological factors in her study on preliminary exercise and vertical jumping by disguising the true purpose of the experiment. Asmussen et al. (1:1) adopted a similar procedure. Hipple (36:246) reported there was no psychological benefit in his study where the subjects ran a series of 50 yard sprints; they were of the impression that the first sprint was part of a speed running contest between classes whereas it was actually the preliminary exercise itself. Karpovich et al. (40:1117) were also unable to find any psychological effect in their study. Smith et al. (93:78) investigated the attitudes of college women toward preliminary exercise using an attitude inventory which indicated whether the subjects had a more or less favourable attitude toward preliminary exercise. They showed that performance improved when preliminary exercise was given to those with a favourable attitude toward it, whereas there was no improvement in performance in those subjects with an unfavourable attitude. The other studies cited simply state that psychological factors most likely did not play a part in the results that were obtained and any improvement shown in the dependent variables can be accredited to changes in the independent variables and not an uncontrolled psychological preparation factor.

But, there is one study conducted by Massey et al. (53:63) with young male adults which attempts to show that it is psychological factors that improve performance and not the preliminary exercise. Prior to the preliminary exercise procedure all subjects were placed in a hypnotic state and consequently did not know if they had participated in the preliminary exercise procedure or not. They were then tested on a speed performance task using a bicycle ergometer where the fastest mean times over 4 trials occurred with the subjects receiving no preliminary exercise. The psychological control was apparently excellent as no subjects gave evidence of being curious concerning their behaviour or activities whilst in the hypnotic state. They then concluded that the results of this research indicate that preliminary exercise is primarily a psychological value and their control by hypnosis eliminated this factor leaving an ultimate detrimental effect from preliminary exercise. Criticisms of this study include the choice of subjects - only certain individuals can be effectively hypnotized.

Some writers have expressed their belief that the psychological preparation is more important than the physiological adaptations. Karpovich states:

> After reviewing literature on warming up

> I have come to the conclusion that although mobilization of various physiological systems (other than CNS) may be beneficial this effect is frequently overshadowed by the intervention of the central nervous system or by so-called psychological effect. (47:169)

There appears two general areas, the first, often labelled "mental readiness," refers to an individual's mental preparation to perform a certain task and attempts, as reported previously, have been made to control for this by keeping their subjects naive as to the true nature of the experiment. The second is a practice effect, or facilitation factor; all movements are controlled by neural patterns which are specific to that particular movement and consequently separate movements must be learned individually. In the skilled athlete minimum conscious control is necessary as he or she is a coordinated performer, but in the less skilled this practice effect alone may produce an improvement on performance on the criterion task. This is particularly important in psycho-motor performance. Related preliminary exercise obviously plays a more dominant role in this facilitation effect. For these reasons it may be beneficial to carefully select subjects for participation in some preliminary exercise research. This could enhance the validity of the final result.

Finally, King et al. (42:8) believe that an expectation of performance may be sufficient to improve the performance. Therefore it would seem there may be psychological factors present so it is adviseable to control for them where possible. Although it appears one can safely say there is a need for psychological preparation prior to an athletic performance to enable individuals to perform at their maximum, the literature available does not suggest that this benefit in performance is equal to that of preliminary exercise, it seems more an integral aspect of that performance.

Closer consideration should be given to the hypothesis that it is the practice effect which causes improved performance and not an exclusive preparation of physiological and/or psychological parameters. Depending on the criterion test this practice effect could play a more dominant role as seen in performances involving complicated skill patterns and extreme accuracy. It seems this facilitation effect is a contributing factor in many studies but many consider it an integral part of preliminary exercise and not a parameter that should be separated. When heavy exercise is the requisite to complete the criterion task as in the marathon, the early minutes of the test exercise itself may produce a sufficient enhancement effect. This within task enhancement may mask any positive effect of the preliminary exercise and may help explain why some investigators were unable to find a performance improvement following the exercise.

The champion athletes that Miller (59:31) interviewed agreed that mental readiness and injury prevention were integral aspects of preliminary exercise - this leads us to a review of the literature concerning preliminary exercise and injury prevention. De Vries (23:305) in a study with 4 college age male athletes running 100 yard sprints stated that when running with no preliminary exercise 2 of the subjects developed muscle soreness that may have been severe without immediate effective treatment. Rasch and Burke state that "the effects of warm-up on the prevention of injury may be even more important than its effect on performance." (77:385) These two statements most likely reflect the opinion of the majority of people involved in this area, that is, preliminary exercise plays an important role in reducing the incidence of injury at the onset of performance. But, a study by Start et al. (96:208) showed that preliminary exercise had little effect on the incidence of muscle injury when strength and speed were measured. A slight discomfort was present when isotonic and isometric endurance were measured. These results are supported by Tremble (105) who looked at the effect of preliminary exercise on injury to the hamstrings muscle. Karpovich et al. (40:1117) tested the efficiency of various forms of preliminary exercise on subsequent performance and found that although the subjects in their control group exercised maximally with no preliminary exercise, no injuries were incurred. Similar findings were reported by Michael et al. (58:357) and Mathews et al. (54:446).

Quotes like the one already presented on preliminary exercise and injury prevention are readily available in almost any relevant text. The problem of demonstrating empirically the effect of preliminary exercise on athletic injuries is a difficult one to approach; obviously we cannot set about injuring, or attempting to injure, our subjects to examine the hypothesis. Indirectly though, the studies available lead us to believe that injury prevention is not one of the beneficial aspects of preliminary exercise. In every study reported in Table 3 there were control, or no preliminary exercise, situations but only in one case (23:305) was there any report of injury when participating without preliminary exercise. Four (53:63, 54:446, 58:357, 77) specifically mentioned the lack of injuries. Delforge (20:108) found that more injuries occurred early in the season when the athletes were in poorer condition - it is possible that the subjects used were in top condition, hence reducing the importance of preliminary exercise.

Although there is little empirical evidence to justify preliminary exercise on the grounds of injury prevention I feel that the plethora of professional opinion in favour of it cannot be ignored. We have experimental evidence to support the physiological changes that occur with preliminary exercise. It is likely that many of these directly or indirectly prepare the individual for activity and aid in the reduction of injuries - particularly muscular.

It seems appropriate at this stage to outline the main physiological changes that occur with preliminary exercise as stated in the literature. Preliminary exercise as a preparation prior to physical work attempts to produce optimum performance by increasing one or more of the following readiness factors - muscle temperature, core or deep body temperature, circulatory efficiency, joint mobility/flexibility. If we can successfully increase the blood, muscle and deep body temperatures there are several areas which are directly or indirectly involved in improved performance that could be affected:

1. Increased speed of contraction and relaxation of muscles; nerve messages travel faster at higher temperatures (4:524). Lowering muscle temperature below normal decreases muscle contractility and capacity for work.

2. Greater circulatory efficiency due to lowered viscous resistance in the muscles and decreased resistance in the vascular bed. Widimsky et al. (110:983) state that preliminary exercise can produce a decrease in total pulmonary resistance of about 13%.

3. With an increase in blood circulation we get an increase in blood volume flowing past the active tissues.

4. Pulmonary ventilation is increased.

5. By performing a preliminary exercise up to 30% of maximal oxygen consumption ($\dot{V}O_2$ max.) the athlete can utilize more oxygen aerobically and in doing so incur a smaller anaerobic debt (35:70).

6. At a higher temperature the exchange of oxygen from the blood to the tissues is more rapid, i.e. hemoglobin gives up more oxygen at higher temperatures and dissociates more rapidly.

7. Myoglobin shows temperature effects similar to those of hemoglobin.

8. Metabolic processes increase their rate with increasing temperature; for each degree of temperature increase (°C) the metabolic rate of the cell increases by about 13% (4:524).

9. Moderate to heavy exercise may increase blood-sugar level; blood-sugar serves to replenish depleted cellular fuel reserves.

Preliminary exercise is used therefore to describe an actual body state during exercise and therefore should be of particular value to the athlete who is performing relatively short-term exercise where the majority of these states would not normally be reached.

In relation to this study a more specific review of the literature concerned with preliminary exercise and a criterion test of speed or endurance on the bicycle ergometer is included.

One of the earliest published studies on preliminary exercise, but still one of the most frequently cited in the current literature, is the work of Asmussen and Bøje (1:1) who demonstrated in 4 trained subjects an improvement of 3.5 to 8.0% in both a short performance (956 kgm/min.) time lasting 12 to 15 seconds and 2.6 to 5.5% in a long performance (9860 kgm/min.) time lasting 4 to 5 minutes on a bicycle ergometer when compared to the results of the group with no preliminary exercise. The preliminary exercise of 660 kgm/min. for 30 minutes preceding the performances increased the rectal temperature up to 0.8° C. They also showed that the results from the group receiving preliminary exercise were better than the "cold" group on both performances. There were no statistical analyses to show if the results of the "warm" conditions were significant when compared to the "cold." In a second experiment similar criterion tests were utilized and the body was "heated" using wave diathermy and by a hot shower (47° C) for about 10 minutes. With the short term performance the radio diathermy improved the performance 4.7 to 6.6% and in the long term performance 3.9 to 7.6% on 4 subjects. With the radio diathermy the rectal temperature was increased 1.5° C from the resting value. Using the hot shower the rectal temperature was raised by 0.5° C and in one subject an improvement of 5.0 to 7.2% was recorded on the short-term performance. Improved results were always shown when the subjects were warm. Massage showed no effect. Again no statistical analyses were performed on the data.

Asmussen et al. (1:1) concluded that the improvements were brought about by an increase in muscle temperature and not by an increase in deep body (rectal) temperature. They showed that the best improvement was achieved when the muscle temperature was virtually stabilized. Whereas the muscle temperature reached an approximate asymptote after 15 minutes, rectal temperature continued to rise throughout most of the exercise period. The performance time and muscle temperature (vastus lateralis) were closely associated and conversely, the rectal temperature was considered to be a minor determinant of performance.

Schmid (85:950) on examining sprint performance on a bicycle ergometer used related, non-related, diathermy, hot showers and massage as varying forms of preliminary exercise and found that all were more beneficial than no preliminary exercise. A related preliminary exercise had the most beneficial effect on the criterion test involving an all-out ergometer ride. The only other reported study that supports the beneficial effects is one by Simonsen et al. (90:152) where he found that non-related preliminary exercise proved advantageous for speed performance on the ergometer.

Research reported by Karpovich et al. (40:1117), Skubic et al. (92:147), Pyke (76:1069) and Schutz (86) display a variety of preliminary exercise procedures, with a dominance for related types, but show no improvement on the criterion test of speed performance on the ergometer.

In relation to endurance performance on the bicycle ergometer there are two studies that support the basic findings of Asmussen et al. (1:1) previously reported. Bonner (9:138), previously quoted for his psychological control, used 60 male subjects and a preliminary exercise period of 10 minutes working at a load between 350 and 950 kpm/min. The criterion task consisted of pedalling for 10 minutes against an initial workload of 1632 kpm/min. His "two factor theory" postulates concurrent facilitatory and fatigue factors resulting from preliminary exercise, the net effect rising to an optimum then declining to eventually become negative as the preliminary task is progressively increased. His results supported the "two factor theory". He found a positive effect at 350 kpm/min., a maximal positive effect at 650 kpm/min., a decline to zero at 800 kpm/min. and a strongly negative effect at a preliminary exercise workload of 950 kpm/min. Secondly, Sucec (101) with 36 college males used a 10 minute preliminary exercise period at 250 and 500 kpm/min, and a criterion task of an all-out ergometer ride at 500 kpm/min. and found that both preliminary conditions were superior to the control condition of no prior exercise.

Conversely, Stewart et al. (98:169) and Massey et al. (53:63) reported that preliminary exercise had no significant effect on their endurance task on the ergometer. One study by Karpovich and Pestrecov (41:300) concluded that no preliminary exercise was actually superior to the experimental condition. No mention was made regarding the training state of the subjects.

There are several additional studies that are concerned with the influence of body temperature upon performance and these are relevant here. Muido (65:102) demonstrated with his 3 subjects that a rise in body temperature before swimming facilitates performance. When the preliminary work consisted of 1080 kgm/min. for 10 minutes on a bicycle ergometer the results showed improvement from 1.4 to 2.6% in the 400 meter freestyle and 200 meter breastroke. The rectal temperature was raised about 0.6° C. When 10 minutes of light jogging and bicycle ergometer work were applied the rectal temperature rose between 0.4 and 0.9° C (mean 0.6° C) and the performances in swimming were improved 0.6 to 2.2% in time. Muido also found that when the subjects rested for 10 minutes before the testing, the rectal temperature showed a fall of only 0.1 to 0.2° C, whereas the muscle temperature showed a greater decrease. This concurs with the idea that [illegible] is more sensitive to change. He then conducted an experiment showing that rectal temperature after 60 minutes of rest was still 0.4° C higher than the rectal temperature in the control condition whereas the muscle temperature had reached the control condition level, or lower. The performance times still showed an improvement of 1.2 to 4.3% after the 60 minutes of rest.

In an additional experiment by Muido (65:102) an improvement in the performance times of 2.0% in the 50 meter freestyle were recorded by the introduction of hot baths (40-43° C) for 15 to 18 minutes prior to performance. An increase in rectal temperature between 1.0 and 1.6° C was noted. Muido therefore concluded that the increase in rectal temperature was responsible for the improvement.

In one of his experiments with swimmers Carlile (11:143) found that the best performances were made when rectal temperature was between 99.1 and 100.9° F (37.28 and 38.28° C). The rectal temperature was found to be between 98.8° F (37.1° C) and 101.6° F (38.6° C) in the 5 subjects after 16 minutes of hot shower at 105° F (40.5° C). When the swim time for 220 yards freestyle was correlated with a rectal temperature of 100.5° C (38.1° C) only one subject out of 5 had improved his time, and hence Carlile concluded that for a rectal temperature below 100.5° F (38.1° C) the swimming time was generally unrelated to rectal temperature, except in this one subject. Unlike Muido he attributed the improved performance to an increase in muscle and not rectal temperature, although it had not been measured.

Work completed in this area has indicated that the deep body temperature (rectal), and probably the temperature in the working muscle, is determined by the relative work load of the individual and not the absolute workload performed (2:64, 16:131, 46:815, 68:120, 84:1757). It appears that subjects working at varying relative workloads, as set by a percentage of $\dot{V}O_2$ max., will not show a significantly different deep body temperature following an identical time of work. Specifically, Astrand (2:64) found in all her subjects a rectal temperature of 38.1° C after 7 hours at a workload equal to 50% $\dot{V}O_2$ max. despite a variation in the oxygen intake during work of 1.1 to 2.7 liters per minute. Extrapolation from the results of Saltin et al. (84:1757) show 2 male subjects reaching a rectal temperature of 38.10° C when both working for 60 minutes at a relative workload equal to about 49% of their $\dot{V}O_2$ max., but, one had a $\dot{V}O_2$ max. of 2.61 liters/min. and the other 5.35 liter/min. A similar pattern is reported with 2 female subjects.

Clasing et al. (16:131) failed to find differences in the rectal temperature in persons with low and high physical performance capacity during 2 hours work at about 45% $\dot{V}O_2$ max. Kozlowski et al. (46:815) reported similar findings when their subjects worked at 35, 50 and 65% $\dot{V}O_2$ max. but found at the higher relative workload rectal temperatures had stabilized after 30 to 45 minutes. Hence, there appears agreement that at lower relative work capacity (less than 50%) temperatures stabilize at a similar level in both high and low physical performance capacity groups. It would also appear then that there is a constant relationship between the intensity of work performed and the deep body temperature (Tr).

As a conclusion to this review of literature I would like to provide some understanding and support for the use of rectal temperature as a measure of deep body temperature. The central or core temperature, which is often measured by rectal temperature, rises gradually during the first hour of work to a new level that is proportional to the relative amount of work performed (64:1296). Neilsen et al. (68:120) report that in 1 hour experiments on a man performing different rates of work in a cool room (22 to 23° C) that the rise of core temperature in work occurs even in cold environments in which heat dissipation is not a limiting factor. They concluded that during work both rectal temperature and esophageal temperatures were practically independent of environmental temperatures between 5 to 30° C.

Astrand et al. (4:493) claim that rectal temperature is a representative indicator for the purpose of assessing changes in the deep body temperature providing the measurement is made under steady state conditions, that is, after at least 30 minutes. The rectal temperature in a resting individual is slightly higher than the temperature of the arterial blood, it is the same as liver temperature and slightly lower (0.2 to 0.5° C) than those parts of the brain where the thermal regulatory centre is located. In making a comparison of rectal temperature with esophageal and muscle temperatures Saltin et al. (84:1757) have shown that when their subjects were working at 50% $\dot{V}O_2$ max. the total range of all 3 temperatures was 38.01 to 38.7° C, with the higher recording being the muscle temperature and the rectal temperature being 38.14° C. Their findings suggest that the rectal temperature is as good an index of the core temperature during work as any and the average difference between esophageal and rectal temperature was only 0.14° C. Only at the highest workload (70%) was this difference significant. Neilsen et al. (68:124) also found only a small difference between rectal and esophageal temperatures.

It appears therefore, that although rectal temperature is not synonymous with muscle and esophageal temperatures only small deviations exist. Therefore the rectal temperature is a sound indicator of deep body temperature even if a somewhat slower responder. Mountcastle (64:1306) states that rectal temperatures are usually about 0.65° C higher than those of the mouth. In the rectum there are variations of 0.1 to 0.9° C depending on the position of the recording instrument. The lowest rectal temperatures are found in those parts of the rectal wall closest to the veins carrying returning blood from the buttocks and legs. Mead et al. (55:97) found a similar situation in their study and emphasized the necessity for accurate positioning of devices for recording internal temperatures. They described a rigid plastic catheter which permits reproducible positioning of a thermocouple against the rectal mucosa sufficiently anterior in the pelvic cavity to be beyond direct influence of the blood temperature in the large vessels of the posterior pelvic wall.

Neilsen et al. (68:120) measured rectal temperature at depths of 12, 17, 22 and 27 centimeters and found very little difference on 57 exposures. Mead et al. (55:97) measured at depths from 3 inches to 8 inches; Saltin et al. (84:1757) from 15 to 17 centimeters; Kozlowski et al. (46:815) at 10 centimeters, and Astrand et al. (4:443) state that rectal temperature is customarily measured from 5 to 8 centimeters. It therefore appears that position is more important than depth.

It is also important that information obtained from research done in the field of physical education be made available to those desiring to utilize it. It therefore becomes necessary for us to meaningfully classify and break down the types of activity involved.

Knapp (79:121) proposes a continuum of skills adapted originally from Poulton (79:121). There are closed skills, which utilize a stereotyped movement pattern in a stable environment and open skills which are less predictable in a constantly changing environment. The ergometer tasks used in many experimental procedures are simply closed skills and involve different skill acquisition patterns than an open skill, or one involving a combination of both open and closed skills.

Under Fitts's Levels of Difficulty (79:129) where tasks are classified according to their degree of difficulty and the processes involved there are 3 levels. The ergometer tasks come under Level 1 where the performer and object are at rest prior to initiation of the action. Level II in Fitts's taxonomy indicates that either performer or object are moving prior to the initiation of the critical element in the movement pattern and Level III that both are motile.

Additional taxonomies are available to further classify human performance and can be consulted if the above mentioned do not effectively enable one to break down a particular activity. Ergometer work then is a closed or Level I skill.

After considering this review of literature, accompanying general statements and the experience from an earlier pilot study some of the shortcomings of the research in this field became evident. Hopefully the experimental procedure utilized in this research will eliminate some of these limitations and allow the results to have a more meaningful application.

APPENDIX B

APPENDIX B

APL PROGRAM TO DETERMINE

PWC $_{135}$, PWC $_{165}$, PWC $_{170}$/KG., PREDICTED VO_2 MAX. (ML/KG/MIN.)

```
      ∇WCT[⎕]∇
     ∇ WCT
[1]    N←ρHR
[2]    SX←+/HR
[3]    WL←PR×6×KP
[4]    SY←+/WL
[5]    →6
[6]    SXSY←SX×SY
[7]    SXS←+/(HR*2)
[8]    XYXY←+/(HR×WL)
[9]    BX←(XYXY-(SXSY÷N))
[10]   BYX←BX÷(SXS-((SX*2)÷N))
[11]   AYX←(SY-(BYX×SX))÷N
[12]   PWF←(BYX×150)+AYX
[13]   PWS←(BYX×170)+AYX
[14]   PWA←(BYX×135)+AYX
[15]   PWB←(BYX×165)+AYX
[16]   →(S=2)/26
[17]   VOL←(0.003×PWF)+0.5
[18]   →(VOL≤3.7)/22
[19]   →(VOL≥4.7)/24
[20]   VOL←VOL+0.1
[21]   →25
[22]   VOL←VOL+0
[23]   →25
[24]   VOL←VOL+0.2
[25]   →27
[26]   VOL←(0.00334×PWF) 0.5
[27]   ACF←1.2-(0.00913×AG)
[28]   CVL←VOL×ACF
[29]   VMK←(CVL÷KG)×1000
[30]   'SUBJECTS ID IS ';ID
[31]   'PWC 150 IS ';PWF
[32]   'PWC 170 IS ';PWS
[33]   'PWC 135 IS ';PWA
[34]   'PWC 165 IS ';PWB
[35]   'PWC 170/KG IS ';PWS÷KG
[36]   'VO2 IN LIT IS ';VOL
[37]   'AGE FACTOR IS ';ACF
[38]   'VO2 IN LIT COR FOR AGE IS ';CVL
[39]   'VO2 IN ML/KG/MIN IS ';VMK
     ∇
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APPENDIX C

APPENDIX C

MODIFIED LATIN SQUARE TO DETERMINE ORDER OF COMPLETION OF CONDITIONS

	CONTROL		T135		T165	
	CT1	CT2	CT1	CT2	CT1	CT2
1	1	2	3	4	5	6
2	2	3	4	5	6	1
3	3	4	5	6	1	2
4	4	5	6	1	2	3
5	5	6	1	2	3	4
6	6	1	2	3	4	5
. . . N						

CT1 = Speed Task

CT2 = Endurance Task

APPENDIX D

APPENDIX U

STATISTICAL ANALYSES (ANOVA15) OF SPEED PERFORMANCE RESULTS

	NUMBER	MEAN	VARIANCE	S.D.
CONTROL	18	13.12	0.994	0.007
T135	18	12.26	0.759	0.871
T165	18	12.75	0.684	0.827
TOTAL	54	12.71	0.893	0.945

VAR SOURCE	SS	DF	MS	F	p
Between	34.613	17	2.036	17.137	<.01
Within	13.609	36	0.378		
Treatments	6.832	2	3.416		
Residual	6.777	34	0.199		
Total	48.223	53			

	I T135	II T165	III C
I T135	-	*	**
II T165		-	-
III C			-

* p<.05
** p<.01

APPENDIX E

APPENDIX E

STATISTICAL ANALYSES (ANOVA15) OF ENDURANCE PERFORMANCE RESULTS

	NUMBER	MEAN	VARIANCE	S.D.
CONTROL	18	3.81	0.206	0.453
T135	18	3.58	0.122	0.350
T165	18	3.79	0.214	0.463
TOTAL	54	3.73	0.182	0.427

VAR SOURCE	SS	DF	MS	F	p
Between	7.623	17	0.448	6.505	<.01
Within	2.199	36	0.0611		
Treatments	0.609	2	0.304		
Residual	1.591	34	0.0468		
Total	9.822	53			

	I T135	II T165	III C
I T135	-	*	*
II T165		-	-
III C			-

* p<.05