AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF THREE INTENSITIES OF WARM-UP ON RUNNING PERFORMANCE

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AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF THREE INTENSITIES OF WARM-UP ON RUNNING PERFORMANCE

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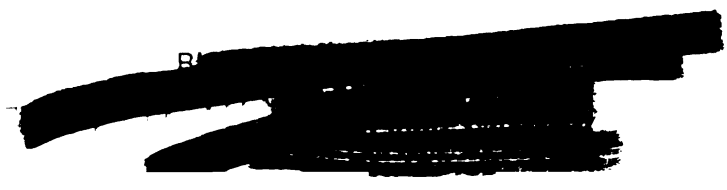

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Robert L. Hasseler

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CHAPTER 1

THE PROBLEM

Numerous studies have been completed comparing the effect of various methods of warm-up on performance. Few studies can be located which compare the effects of performance with varying intensities of the same warm-up. This constitutes the purpose of this study.

Today, as the four minute mile is being constantly achieved, more and more attention is being directed toward those factors which affect and are responsible for running performance. Such factors include: conditioning and training, diet, warm-up and mental attitude.

The available literature reveals the inconsistency of proof of warm-ups affect on performance. There is general acceptance that warm-up is beneficial in the prevention of injury. Disagreement exists as to how warm-up may be advantageous. Hypotheses include: (1) the increase of blood circulation and oxygen availability to the cells (2) the decrease of physical and psychological tension (3) the prevention of muscle strain (4) the raising of the muscle temperature and increasing of the functional efficiency of muscles and organs and (5) the raising of the blood and body temperature to increase efficiency.

Runners encounter difficulty in determining the amount of warm-up necessary or desirable for best results. A team member may employ an outstanding runner's warm-up although it may be less advantageous to his performance. Coaches should utilize research and experience in developing a warm-up which will not detrimentally affect performance.

It is entirely possible that the warm-up necessary for optimum performance may be an individual problem.

Statement of the problem. The purpose of this study is to determine the effect on the length of an all-out run on the treadmill of:

(1) no warm-up

(2) a modified warm-up; one minute and thirty seconds of running on the treadmill at 8.01 miles an hour, preceded by the following calisthenics and then waiting ten minutes before an "all-out" run.

(A) five vertical jumps - counting 1,2,3,4 - 2,2,3,4 - 3,2,3,4, etc.

(B) five toe touches with the legs straight - same count

(C) five hurdle stretches on each leg - same count

(3) a vigorous warm-up; two minutes of running on the treadmill at 9.14 miles per hour, preceded by the following calisthenics and then waiting fifteen minutes before an "all-out" run.

(A) these exercises are the same as those for modified warm-up. The duration has changed from five to eight.

(B) eight vertical jumps - same count
eight alternate toe touches - same count
eight hurdle stretches - same count

A treadmill was utilized to establish a situation in which the pace variant in the "all-out" run could be controlled, as well as making it possible to measure temperature and humidity. The psychological variant can never be completely controlled. The variability of this factor should be relatively constant in each of the twenty-one runs of each subject.

Importance of the study. The assumption that warm-up before vigorous activity decreases injury, such as muscle strain, has merit through

long use and should be followed until more proof is available. There is inconsistency in research results of warm-ups effect on performance. Some experimenters such as Hale,[1] indicate that warm-up does not improve performance. Others, such as Thompson,[2] suggest that there is benefit. Even assuming that warm-up is effective, the problem remains of deciding what degree or type is most significant in positively affecting performance. If significant results are attained in this study, some indication of the degree of warm-up for best performance will be obtained.

Limitations of the study. Ensuing results are derived from data from the five subjects. Each runner has twenty-one recorded times, providing depth and consistency to validate generalization from the results.

These subjects were not trained runners and were given no instruction in running form, breathing or arm usage.

The study does not presume to determine the best warm-up per individual for endurance running. The interest lies in the degree of warm-up which best improves performance, not how the condition is attained. The calisthenics, distances and speeds selected were arbitrary and should not necessarily be followed in light of favorable results.

The data will in no way indicate that any degree of warm-up is best for controlling the number and degree of injuries.

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[1]C.J. Hale, Effect of Preliminary Massage on the 440 Yard Run. Unpublished Master's Thesis, Springfield College, Massachusetts, 1942, p. 49.

[2]Hugh Thompson, "Effect of Warm-up Upon Physical Performance in Selected Activities." Research Quarterly, 29:231, May 1958.

The reader must determine if the results obtained from college freshmen are applicable to young high school runners or to older runners with a great deal of experience and training. Determine also if a run of 9.14 miles per hour on an eight and one-half degree incline is a speed run as well as an endurance run and if the warm-up showing the best statistical significance can be applied to warm-up for a sprint race.

Investigation should be attempted utilizing more varied temperatures to measure that effect on performance. Varied distances and speeds should be studied to compare observed results. Finally, trained runners should be studied and the results compared with untrained runners. Perhaps practice warm-ups should vary considerably; dictated by the distance to be run and the individual who is running.

CHAPTER II

RELATED LITERATURE

Various approaches have been incorporated in attempting to solve the problem of the effect of warm-up on performance. The available literature indicates that the intensity and duration of the warm-up, the type of subject used; trained or untrained, and the type of warm-up used may all be contributing factors in the ensuing results. Some investigators found warm-up beneficial, while others claimed no effect or a detrimental result. Variance of results of previous studies leave some impression as to the divergent methods of attacking the problem and of the conflicting results.

These studies are grouped as to positive and negative results, each group then being chronologically arranged.

Asmussen and Boje[1] used preliminary work, short wave diathermy, hot baths, showers and massage as techniques of warm-up. The subjects ran sprints and endurance runs. The authors measured increase in work capacity with these results: (1) preliminary warm-up increased work capacity 5.88% for sprints and 4.00% for endurance runs (2) diathermy increased work capacity 5.52% for sprints and 5.77% for endurance runs (3) hot baths showed an increase of work capacity for the sprints of 6.10% (4) massage had least effect with .66% for sprints and 1.81% for endurance runs. Asmussen and Boje concluded that these increases were

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[1] E. Asmussen and O. Boje, "Body Temperature and Capacity for Work." Acta Physiologica Scandinavica, 10:1, 1945.

due to an increase in muscle temperature.

Muido[2] also found significant improvement after warm-up when paralleling the study of Asmussen and Boje. He credited his results to an increase in blood temperature.

Subject	Influenced by	Per Cent of Improvement
3	preliminary work	1.4 - 2.6
3	hot baths	1.9 - 2.1
2	diathermy	1.3 - 1.9

Blank[3] tested sixteen track and field athletes in the 120 yard run and 38 non-athletes in the 100 yard run. He found a significant difference ($p = .01$) in improved running time in favor of warm-up.

Carlile[4] tested ten swimmers in a 200 yard swim for time and found a significant improvement ($p = .01$) in performance time after an eight minute hot shower. There was some variability with one boy's time becoming slower. Carlile concluded that eight minutes may be too long for some individuals and suggested that some passive pre-race heating of the body plus active work constitute a valuable adjunct to warming-up in temperate climates.

Swegon, Yankosky and Williams[5] tested male college students on repeated trials of the preferred arm extension movement. Each trial

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[2]Leond Muido, "The Influence of Body Temperature on Performance in Swimming." Acta Physiologica Scandinavica, 12:102, 1946.

[3]Lane B. Blank, "Effects of Warm-up On Speed," Athletic Journal, 35:10, February 1955.

[4]Forbes Carlile, "Effect of Preliminary Passive Warming on Swimming," Research Quarterly, 27:143, May 1956.

[5]Donald Swegon, Gene Yankosky, James A. Williams, "Effect of Repetition Upon Speed of Preferred Arm Extension," Research Quarterly, 27:74, May 1956.

resulted in faster movement. Fifty trials were better than twenty. The authors concluded that (1) individuals vary considerably in successive repetitions of the simple movement of arm extension (2) Repetition, as a form of warm-up, tended to produce faster movement times.

Pachero[6] tested vertical jump performance with the Henry apparatus with:

no warm-up
isometric stretching before the jump
stationary running (isotonic) before the jump
knee bends (a combination of the previous jump)

All of the following results were significant. (1) stationary running was 4.79% more effective than knee bends (2) stationary running was 2.68% more effective than stretching (3) stretching was 2.05% more effective than knee bends. In comparison to no warm-up these results were obtained: (1) knee bends were 2.88% higher (2) stretching was 4.98% higher (3) running in place was 7.8% higher. This would seem to indicate that warm-up is beneficial in a power activity.

Michael, Skubic and Rochelle[7] used no warm-up, related warm-up and unrelated warm-up, in testing the effect of each on the softball throw. Related warm-up consisted of tossing and catching a ball at five various distances for one minute each. Unrelated warm-up included one minute each of jumping jacks, toe touching, alternate toe touching, and two minutes of sprint running.

Throws after the unrelated warm-up were 7 $\pm$ 2.17 feet farther

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[6]Betty Pachero, "Improvement in Jumping Performance Due to Preliminary Exercise," Research Quarterly, 28:55, March 1957.

[7]Ernest Michael, Vera Skubic, Rene Rochelle, "Effect of Warm-up on the Softball Throw for Distance," Research Quarterly, 28:357, December 1957.

than no warm-up. Throws after related warm-up were 5 ± 1.75 feet farther than no warm-up. Both are significant at the P = .01 level.

Thompson[8] compared scores of five selected activities after no warm-up, formal warm-up, and informal warm-up. Formal warm-up consisted of the activity to be performed while informal warm-up included general and free exercise, such as arm swinging, stationary running, etc.

Activity	Formal VS. No Warm-up	Informal VS. No Warm-up
Swimming		
speed	CR (3.96) .01	CR (1.68) not at .05
endurance	CR (2.13) .01	CR (.56) not at .05
BB foul shoot	CR (9.07) .01	
Bowling		
accuracy	CR (2.94) .01	
Typing		
speed	CR (.53) not at .05	CR (1.92) not at .05
accuracy	CR (1.35) not at .05	CR (.75) not at .05
Strength (leg dynamometer)	CR (.06) not at .05	

There appears to be wide variability in the effect of warm-up on individual performance. Formal warm-up improved group performance in swimming, foul-shooting and bowling at the P = .01 level of significance.

DeVries[9] compared no warm-up, a swimming warm-up of 500 yards, a six minute hot-as-possible shower, calisthenics and massage, each done before competitive 100 yard swims.

Warm-up for the whole group improved times by a mean difference of .44 seconds. (P = .05) Considering the group as a whole, hot

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[8]Hugh Thompson, "Effect of Warm-up Upon Physical Performance In Selected Activities," Research Quarterly, 29:231, May 1958.

[9]Herbert A. DeVries, "Effects of Various Warm-up Procedures on 100 Yard Times of Competitive Swimmers," Research Quarterly, March 1959, p. 11.

showers, calisthenics and massage had no significant effects. On the seven freestylers calisthenics had the only significant effect (.37 seconds). Calisthenics had the only significant effect with the breaststrokers (1.52 seconds) (P = .01).

DeVries concludes that time can be improved by proper warm-up and can be impaired by improper warm-up. The type of warm-up is dependent on the stroke used. Calisthenics implement best results where strength in the stroke plays a large role.

The following studies show warm-up to either not affect performance or to cause detrimental results.

Karpovich and Pestresoy[10] showed that riding times on a bicycle ergometer were actually reduced when a warm-up was taken prior to the ride.

Hale[11] studied the effects of massage on the 440 yard run in relation to performance. He used preliminary exercise, massage and digital stroking as forms of warm-up. The first of two experiments was in the spring on an outdoor track. The second was on an indoor track.

EXPERIMENT ONE

Warm-up	Mean Time	Per Cent of Increase
massage	55.84	1.17
preliminary ex.	56.17	.58
digital stroking	56.50	--

[10]Peter V. Karpovich and K. Pestresoy, "Effect of Gelatin Upon Muscular Work in Man," American Journal of Physiology, 134:2, 1941.

[11]C. J. Hale, Effect of Preliminary Massage on the 440 Yard Run. Unpublished Master's Thesis, Springfield College, Massachusetts, 1942, p. 49.

EXPERIMENT TWO

no warm-up	59.21	.39
digital stroking	59.44	--

Hale stated that he cannot compare the two different groups because of environmental conditions. There was no significant improvement in performance, however, so he concluded that neither massage, preliminary exercise, nor digital stroking increased performance in the 440 yard run.

Hipple[12] ran eighth grade boys a maximum all-out 50 yard run as a warm-up. He then ran his subjects five times at 50 yards with a five minute rest between each. The first race had no beneficial effect on the second. Fatigue was observable during the fourth and fifth runs. Hipple concluded that warm-up is not important for eighth grade boys.

Possibly all-out runs are not good warm-ups. Care must be taken in generalizing from this study in application to older athletes.

Sills and O'Reilley[13] measured the number of times the right foot hit the ground in five ten-second bouts of spot running, using rest, exercise and cold application as warm-up. Each improved performance to some degree, rest more so than exercise.

Karpovich and Hale[14] pointed out that there were no significant

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[12]Joseph Hipple, "Running Warm-up and Fatigue in Junior High School Sprints," Research Quarterly, 26:246, May, 1955.

[13]Frank Sills and Vernon O'Reilley, "Cold Spray Compared to Rest and Exercise in Effect on Performance," Research Quarterly, 28:217, May 1956.

[14]Peter V. Karpovich and C. J. Hale, "The Effect of Warming-up Upon Physical Performance," Journal of American Medical Association, 162:1117, November 1956.

differences in the running times of the 440 yard run or the sprint type ride on the bicycle ergometer when either preliminary exercise, deep massage or digital stroking methods of warm-up were used. No significant differences resulted when these methods were compared to no warm-up scores of the same activities.

Skubic and Hodgkins[15] tested the effect of warm-up on speed, accuracy and strength including, riding the bicycle, basketball shoot, softball throw. Warm-up included three groups; no warm-up, general warm-up and related warm-up. In none of theses three groups was there a significant difference in scores. This is in opposition to Thompson and Michael, Skubic and Rochelle who used similar warm-up groupings.

The authors concluded that light warm-up of short duration has no affect on performance. Scores were slightly better when preceded by related warm-up, although not significantly.

Lotter[16] measured the effect of warm-up, stationary running while swinging the arms in a complete circle, on the maximum rate of repeated arm-shoulder movements. There was no significant difference after two minutes of warm-up or after four minutes.

He concluded that warm-up was without effect here and that speed of movement on the second crank-turning test was faster due to the result of practice.

The reader must now be aware of the contradictory evidence

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[15]Vera Skubic and Jean Hodgkins, "Effect of Warm-up on Speed, Accuracy and Strength," Research Quarterly, 28:147, May 1957.

[16]William Lotter, "Effects of Fatigue and Warm-up on Speed of Arm Movements," Research Quarterly, May 1958, p. 57.

concerning the effectiveness of warm-up, even when the same general types of warm-up are used. This indicates that intensity is extremely important in determining the worth of any particular practice. A knowledge of the positive effects of general areas of intensity of warm-up would be useful in solving the warm-up controversy. Determining the effect of no warm-up, a modified warm-up and a vigorous warm-up on performance would be very beneficial in identifying areas in which more detailed work should be done, as well as different types of warm-up of this intensity. This constitutes the basis for this study.

CHAPTER III

DESIGN OF THE EXPERIMENT

This study involved five male college students. Four ran on the treadmill three days a week; Monday, Wednesday and Friday for seven weeks and one ran only Mondays and Fridays for seven weeks.

Before recording any scores, a two week training period was utilized to familiarize all subjects with the routine and to decrease variability in scores except for the training variable. Improvement was largely continuous and linear.

The variables consisted of three types of warm-up differing in degree of intensity. Each subject used a different warm-up on different days of the week according to the accompanying chart (Fig. 1, page 14). At the end of each week each subject had run each of the three different groups. After the specified warm-up, the runner mounted the treadmill and ran at the set speed of 9.14 miles per hour. This was an all-out run. The mill was inclined eight and one-half degrees. Scores were recorded until there were seven sets of data for four of the runners and five sets for the fifth runner.

Subjects. The subjects were all male college freshmen who were interested in improving their physical condition and fitness. Four of them were motivated by their plans to "try-out" for a spring sport and wished to develop and/or maintain condition. They realized that there were no material rewards for participation. The subjects ran from three to

FIGURE 1

1 - no warm-up
2 - modified warm-up
3 - vigorous warm-up

Month - Day	Subjects				
	TALLMAN	ALLIS	COOL	FOULKE	LEMASURIER
Jan. 26 Monday	3	1	3	1	2
" 28 Wednesday	1	3	2	3	1
" 30 Friday		2	1	2	3
Feb. 2 Monday	2	2	1	2	3
" 4 Wednesday	2	1	3	1	2
" 6 Friday		3	2	3	1
Feb. 9 Monday	3	3	2	3	1
" 11 Wednesday	1	2	1	2	3
" 13 Friday		1	3	1	2
Feb. 16 Monday	1	2	1	2	3
" 18 Wednesday	2	3	2	3	1
" 20 Friday		1	3	1	2
Feb. 23 Monday	3	3	2	3	1
" 25 Wednesday	2	1	3	1	2
" 27 Friday		2	1	2	3
Mar. 2 Monday	1	1	3	1	2
" 4 Wednesday	3	2	1	2	3
" 6 Friday		3	2	3	1
Mar. 9 Monday	1	2	3	2	1
" 11 Wednesday	3	3	2	3	2
" 13 Friday		1	2	1	3
Mar. 16 Monday	2				

five in the afternoon on their designated days, each running approximately the same time each day. To the author's knowledge, there was no previous vigorous activity for two hours before any run. The subjects were asked to walk to each session, two having only to go next door after sitting in class. They dressed in the laboratory where the treadmill was located and also showered there. At no time was any subject led to believe that one method of warm-up was superior to another in positively affecting performance. The runners reported that they neither ate nor drank anything one hour previous to their run. The runners did not know how the treatment of data was done. The author took no stand as to which group was best.

Methods of establishing schedules and collecting data. In the performance run after warm-up the time the runner remained on the bed of the mill was initiated when both feet touched the bed and completed when both feet left the bed. The runner ran "all-out" until he could not keep the pace, resulting in drifting toward the back of the mill. The legs were always first to give out making recognition of an "all-out" performance relatively easy. There were two "spotters" at all times who caught the runner as he came off the back of the mill.

One revolution of the tread was measured so that the distance of each run could be computed. The number of revolutions per minute at 9.14 miles per hour was forty-four.

If a subject missed a run, the next scheduled run used the warm-up missed, with each successive warm-up being moved one day beyond its original schedule. There were a total of three such instances.

The preceding chart shows a group schedule designed to eliminate

a certain warm-up always occurring on the same day. Any variation, for example, might have been the result of the week-end rather than the warm-up.

Temperature and humidity were kept on each runner each time he ran, recording just as he stepped on the mill.

Controls. In using the treadmill in the laboratory, factors can be eliminated which would be variable on the track. Wind and the effect of other elements can be controlled or eliminated.

Any pace change during the "all-out" run can be greatly eliminated. The subject must run at the set speed as long as he can hold that pace. Outside, one could not be sure of this. This establishes a constant in each of the runs.

The runners saw only daily scores, not associating them with the three groups as to which was developing the best mean time. In this way no trend was initiated to unconsciously create a bias.

When running, the subjects were given the times at one minute, two minutes and then each half minute in every case.

The treadmill rotations were checked every second week to make certain that the number of revolutions per minute remained constant.

CHAPTER IV

ANALYSIS AND PRESENTATION OF THE DATA

The problem of identifying a warm-up which has an optimum effect on performance for an individual has motivated this study. Five Michigan State University freshmen participated in this experiment.

The subjects' "all-out" times were recorded after each of three intensities of warm-up. Temperature and humidity for each run was also recorded.

The results of the analysis of variance using four subjects is shown in Table 1. This table shows that a significant variation of

TABLE 1

ANALYSIS OF VARIANCE

3-WAY CLASSIFICATION

FOR 4 SUBJECTS, 3 INTENSITIES OF WARM-UP

7 REPETITIONS FOR TRAINING

Source	Sum of Squares	Degrees of Freedom	Variance Estimate	F Value	Sig.
Subjects (Blocks)	36.793	3	12.264	219.000	.001
Warm-up (Columns)	.900	2	.450	8.056	.001
Training (Rows)	6.363	6	1.061	18.946	.001
Interaction (S&W)	.956	6	.159	2.839	.01-.05
Interaction (S&T)	1.854	18	.103	1.839	.05-.06
Interaction (T&W)	.625	12	.052		
Interaction (S&T&W)	2.068	36	.057		
T&W plus S&T&W	2.693	48	.056		

run times between individuals exists. The F score was approximately 27 times the number needed for the .1 percent level of significance. Training had a definite effect on the performance time of the subjects as a group (P = .1%), showing that the "all-out" runs lengthened as repetitions increased. The table also reveals warm-up having a significan effect (P = .1%) on the subjects' performances as a group.

The experiment was designed so the interaction of warm-up (W) and Training (T) would be insignificant. The schedule of each subject using each warm-up on different days of each week guaranteed no subject recording a number of scores of the same warm-up in the same week. Because this interaction was insignificant it could be combined with the triple interaction to provide greater degrees of freedom.

In studying the interaction of subjects and training, an F of between the 5 and 6 percent level of significance suggested that the effect of training varied among subjects.

The interaction of warm-up and the subjects resulted in an F score between the .1 and 1 percent level of significance. This signified that the effect of warm-up on subject performance varies from person to person.

The analysis of variance in Table II disclosed the significance of any variance in warm-up for each subject.

With the first subject, the variation was significant, having six times the F score needed. The second and fourth subjects had insignificant variation. The third runner had an F score between the .1 and 1 percent level of significance. The fifth runner had an F score at the 7 percent level of significance, showing some variation in performence with warm-up. The training effect on performance was significant

TABLE II

ANALYSIS OF VARIANCE

2-WAY CLASSIFICATION PER SUBJECT

Subject	Source	Sum of Squares	Degrees of Freedom	MS	F	Sig.
1	Total	5.06	20			
	Training	2.97	6	.495	38.077	.001
	Warm-up	1.94	2	.970	74.615	.001
	Within	.15	12	.013		
2	Total	2.854	20			
	Training	1.654	6	.274	2.978	.06
	Warm-up	.106	2	.053	.576	insig.
	Within	1.103	12	.092		
3	Total	2.075	20			
	Training	1.278	6	.213	8.520	.001
	Warm-up	.503	2	.252	10.080	.01-.001
	Within	.294	12	.025		
4	Total	2.769	20			
	Training	1.582	6	.264	3.034	.05
	Warm-up	.149	2	.075	.862	insig.
	Within	1.038	12	.087		
5	Total	2.770	15	.499	8.911	.01-.001
	Training	1.996	4	.165	2.946	insig.
	Warm-up	.329	2	.056		
	Within	.445	8			

at the .1 percent level of significance for two subjects, between the .1 and 1 percent level for another, at the 5 percent level for another and between the 5 and 6 percent level for the fifth runner.

Table III (p. 20) shows the insignificant effect of temperature on performance in this study. The range of the temperatures should be noted. The study of temperature extremes and variations are not attempted here. The temperature and humidity were recorded as a measure

TABLE III

ANALYSIS OF CO-VARIANCE

BETWEEN TEMPERATURE* AND "ALL-OUT" PERFORMANCE

Subjects	F Value Attained (regression ratio)	Degrees of Freedom	F Needed for P = .05	Correlation Coefficient
1	.696	1 and 11	4.84	-.362
2	.710	1 and 11	4.84	-.095
3	.890	1 and 11	4.84	-.212
4	1.560	1 and 11	4.84	.109
5	1.780	1 and 7	5.59	-.255

*Temperature Range - 70° - 89°
Temperature Mean - 75.94°

of control; showing that the small variation of each had no significant effect on the "all-out" runs. Neither the value attained for F nor the correlation coefficients were significant.

The insignificant effect of humidity on the "all-out" runs was calculated in Table IV (p. 21). Again, the range of degrees should be noted. The regression ratios were not significant, nor were the correlation coefficients. The effect of humidity per subject can be observed.

TABLE IV

ANALYSIS OF VARIANCE

BETWEEN HUMIDITY* AND "ALL-OUT" PERFORMANCE

Subjects	F Value Attained (regression ratio)	Degrees of Freedom	F Needed for P=.05	Correlation Coefficient
1	.181	1 and 11	4.84	.227
2	1.010	1 and 11	4.84	.310
3	.119	1 and 11	4.84	-.081
4	1.340	1 and 11	4.84	-.133
5	.104	1 and 7	5.59	.081

*Humidity Range - 29% - 52%
Humidity Mean - 36.93%

The mean difference of performance, in seconds, after the three intensities of warm-up for each subject, is seen in Table V (p. 22). Notice that for each runner the modified warm-up produced a better mean "all-out" run time than no warm-up.

TABLE V

DIFFERENCE OF MEANS IN SECONDS

	Modified Warm-up (+) and No Warm-up (-)	Modified Warm-up (+) and Vigorous Warm-up (-)	Vigorous Warm-up (-) and No Warm-up (+)
1	+28.9	+ 6.84	-22.08
2	+17.1	+21.48	+ 4.38
3	+ 1.5	+ 9.48	+ 7.98
4	+ 2.52	+10.74	+ 8.22
5	+ 9.66	+13.68	+ 4.02

The same is true in comparing modified warm-up with the vigorous warm-up, although the variations should be noted. This difference in times was significant for two subjects and insignificant for three subjects. It is interesting to observe that for four of the subjects the mean times for the vigorous warm-up were less than the no warm-up means. One runner had a difference which almost equalled the sum of the other four means. Recall that fifteen minutes of resting was allowed between warm-up and performance in the vigorous warm-up. Perhaps too vigorous a warm-up before a performance can result in a detrimental effect which might be due to an oxygen debt built up before the run begins.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Five male college freshmen ran "all-out" on a treadmill a total of 21 times each. Before each run, each subject utilized one of three intensities of warm-up, resulting in seven performances after each warm-up. The purpose of the experiment was to determine the effect of three intensities of warm-up on performance and to ascertain if the effect varied with the individual.

The statistical treatment shows that warm-up significantly affected group performance ($P = .001$). Warm-up was significant for two subjects, insignificant for three. The modified warm-up, in each case, resulted in better means times than no warm-up or vigorous warm-up.

Conclusions

The following conclusions appear justified on the basis of the statistical data presented:

1. Within the limits of this experiment neither temperature nor humidity significantly effected performance.
2. The effect of warm-up on performance for the subjects as a group was significant, but varied with the individual.
3. The mean score for each subject was higher after a modified warm-up than after either no warm-up or a vigorous warm-up.
4. Caution should be a concern in utilizing a vigorous warm-up before performance, as the data suggests such a warm-up may be detrimental to performance.

Recommendations

The following recommendations are proposed for related study involving warm-up.

1. Develop a parallel study to observe the effects of these warm-ups on speed running.
2. Employ trained runners as subjects while using initially the same methods as in this study.
3. More comprehensive research should be attempted in learning the effect of vigorous warm-up on performance.

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[redacted]

AN EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF THREE INTENSITIES OF WARM-UP ON RUNNING PERFORMANCE

An Abstract

Presented to

the College of Education of

Michigan State University of

Agriculture and Applied Sciences

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Department of Health, Physical Education,

and Recreation

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by

Robert Lawrence Hasseler

June 1959

Approved Henry J. Montoye

Robert Lawrence Hasseler

ABSTRACT

Title

An Experimental Investigation of the Effects of Three Intensities of Warm-up On Running Performance

Introduction

The problem of determining and applying an optimum warm-up before performance has long existed in physical education and athletics. The controversial results of studies completed on the subject have served to further confuse and delay decisions of practical application. A review of the literature and the results of this study suggest to the author that the benefits of warm-up are dependent upon the type, relatedness and intensity of the warm-up activity. Many of the related studies cite conclusions in terms of the group tested. Perhaps a partial answer to the warm-up question is the variation of effect per individual.

Review of the Literature

Some researchers have concurred preliminary warm-up to be beneficial before performance (1,2,3,4,10,11,12,15). Others found warm-up to have no affect or a detrimental affect on performance (5,6, 7,8,9,13,14,16). Related warm-up was beneficial in the following studies (1,2,4,10,11,15). A running warm-up positively affected performance in some studies (1,2,11), in others performance was not improved (5,6,7,16).

Methodology

Five male college freshmen ran "all-out" on a treadmill after

each of three varying intensities of warm-up. These consisted of: no warm-up; calisthenics and 1½ minutes of running on the mill at 8.01 miles per hour with the bed of the mill pitched at 8½ degrees and 10 minutes of rest before the "all-out" run; calisthenics and 2 minutes of running on the mill at 9.14 miles per hour with 15 minutes of rest before the "all-out" run. The calisthenics consisted of five and eight repetitions respectively, of jumping jacks, alternate toe touches and the the hurdle exercise. Four subjects ran a total of 21 times, utilizing each warm-up seven times. The fifth subject ran a total of 15 times, having run each warm-up five times.

Temperature and humidity were recorded with each run to determine if either significantly affected performance in this study.

A schedule was established so the same warm-up was not run on the same day of each week. The data was collected over a seven week period.

Results

The mean performance times for each subject, after each of the three warm-ups, are shown in table 1.

The modified warm-up produced a better mean "all-out" run time than either no warm-up or vigorous warm-up. The wide variations of time among individuals when comparing the warm-ups suggests varying affects on the individual. It is interesting to observe that for four of the subjects the mean times for the vigorous warm-up were less than the no warm-up means, while one runner had a difference in means which almost equalled the sum of the other four mean differences. It should be

recalled that fifteen minutes of resting was allowed between the vigorous warm-up and performance.

TABLE 1

MEAN TREADMILL RUN TIME

Subject	No Warm-up	Modified Warm-up	Vigorous Warm-up
1	4:13.6	4:42.5	4:34.7
2	2:48.2	3:05.3	2:43.9
3	2:56.9	2:58.4	2:48.9
4	3:36.5	3:39.0	3:28.3
5	3:10.3	3:19.9	3:06.8

The results of Table II show that warm-up significantly affected group performance, ($P = .001$) as did training ($P = .001$).

A significant F value for subject and warm-up interaction gives statistical evidence that there is individual difference in the affect of warm-up on the subjects.

An analysis of variance per subject shows that warm-up significantly improved performance for two subjects, and was insignificant for three.

An analysis of co-variance shows that the variations of temperature and humidity were small enough to be insignificant, in every case, in their affect on performance.

TABLE II

ANALYSIS OF VARIANCE, 3-WAY CLASSIFICATION

FOR 4 SUBJECTS, 3 INTENSITIES OF WARM-UP

7 REPETITIONS FOR TRAINING

Source	Sum of Squares	Degrees of Freedom	Variance Estimate	F Value	Sig.
Subjects (Blocks)	36.793	3	12.264	219.000	.001
Warm-up (Columns)	.900	2	.450	8.046	.001
Training (Rows)	6.363	6	1.061	18.946	.001
Interaction (S&W)	.956	6	.159	2.839	.01-.05
Interaction (S&T)	1.854	18	.103	1.839	.05-.06
Interaction (T&W)	.625	12	.052		
Interaction (S&T&W)	2.968	36	.057		
T&W plus S&T&W	2.693	48	.055		

Conclusions

The following conclusions appear justified on the basis of the statistical data presented.

1. The effect of warm-up on performance for the subjects as a group was significant, but varied with the individual.
2. The mean score for each subject was higher after a modified than after either no warm-up or a vigorous warm-up.
3. Within the limits of this experiment neither temperature nor humidity significantly affected performance.
4. Caution should be a concern in utilizing a vigorous warm-up before performance, as the data suggests such a warm-up may be detrimental to an individual's performance.

Recommendations

The following recommendations are proposed for related study involving warm-up.

1. A parallel study should be made to observe the effects of these warm-ups on speed running.
2. Trained runners might be employed as subjects while using initially the same methods as in this study.
3. More comprehensive research should be attempted in learning the effect of vigorous warm-up on performance.

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