COMPARATIVE EFFECTS OF THREE EXPERIMENTAL WARM-UP CONDITIONS UPON ACCURACY

By

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ABSTRACT

Two problems were examined with respect to the influence of various preliminary warm-up procedures upon accuracy as measured by the basketball free throw; first, the hypothesis that scores following a related warm-up will be higher than scores without a warm-up or scores following an unrelated warm-up; second, that there will be no significant difference between performance following an unrelated warm-up and performance without preliminary warm-up exercise.

Ten highly skilled basketball players were selected to serve as subjects in the experiment. Each player was tested nine times, three times after each of the conditions of (a) no warm-up, (b) related warm-up, and (c) unrelated warm-up. The order of the experimental conditions was rotated to balance out possible learning effects and to minimize the error that might be caused by systematic sequence of testing.

Results indicated that the related warm-up was significantly more effective in producing better shooting scores than either the unrelated warm-up or shooting without a preliminary warming-up. Secondly, there was no significant difference between scores obtained without a warm-up and scores made following an unrelated warm-up.

It was concluded that where a related warm-up is at all possible this method is recommended over the unrelated warm-up and no warm-up to facilitate an increase in basketball free throw accuracy.

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CHAPTER I

STATEMENT OF THE PROBLEM

It is almost axiomatic with coaches and athletes that a preliminary warming-up is indispensible for optimum performance in any athletic event. The type and duration of the warm-up procedure varies, depending upon the country, the coach, the sport and the individual preference of the athlete. The effects of warm-up and how much warm-up is needed before attempting physical activity is of extreme importance to the coach and to the athlete.

The purpose of the study, broadly stated, was to investigate the effects of different types of warming-up procedures on accuracy in basketball shooting. More narrowly, the objective of the investigation was to determine the effects of a related warm-up, an unrelated warm-up, and no preliminary warm-up on accuracy in shooting ten basketball free throws.

It is hypothesized that:

(1) Performance following a related warm-up will be better than performance following an unrelated warm-up or performance without a preliminary warm-up.

(2) There is no significant difference between performance following an unrelated warm-up and performance without a preliminary warm-up.

Definitions of Terms Used

(1) Warm-Up - Warm-up is the preparation carried out immediately before physical work with the intention of producing optimum work performance.

(2) Related Warm-Up - Exercise in which the movements are those that imitate the activity for which the performer is getting ready.

(3) Unrelated Warm-Up - Exercise in which the movements are generally free movements undertaken solely for raising the temperature of the muscles.

(4) No Warm-Up - The absence of activity just prior to test performance.

(5) Free Throw - The free throw is (2, p. 16);

"An unhindered try for a goal from within the free throw circle and behind the free throw line."

The free throw line is fifteen feet from and parallel to the face of the backboard, to which the basket is attached.

Delimitations

(1) The test item selected to measure accuracy was the number of successful basketball free throws a subject could score in ten attempts.

(2) Ten University students with an age range of nineteen to twenty-four years were tested. All ten were members of the University of British Columbia Men's

Varsity Basketball Team.

(3) The team had completed four months of intensive training prior to the testing.

(4) The more experienced members of the team were selected because it was felt that they would produce more consistent results. Therefore, the results obtained are specific to this group and it is not possible to generalize to larger populations. However, generalizations could be made to other high calibre basketball players and teams.

Limitations

(1) Testing could not be done on consecutive days because of scheduled contests.

(2) Subjects were encouraged to do their best each testing session but it was impossible to control the motivational factor.

(3) An assumption was made that the selected warm-ups were of appropriate nature and of sufficient intensity and duration to serve the purposes of the related and unrelated warm-ups as defined in this study.

(4) This study was confined to a consideration of the relative affects of three chosen warm-up procedures upon a selected measure of physical performance. Its ultimate purpose was to obtain information about warm-ups insofar as optimum performance is concerned and

thereby to provide implications for the worth of each of these warm-up methods in practical procedures.

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CHAPTER II

JUSTIFICATION OF THE PROBLEM

Civilization has always held precedent in very high regard. If we are to progress, however, the value of precedent must continually be questioned. In athletics we have been somewhat less than questioning in our attitude toward acceptance of many of our past procedures. Warming-up before physical activity is a perfect example.

Warm-ups have been used for many centuries. In most cases methods have been passed down from athlete to athlete and from coach to coach with never a doubt as to their true value. John W. Bunn, in his book on the scientific principles of coaching athletics states (1, p. 7):

> I have been disturbed by the tendency in others to accept blindly the methods employed by the star athlete and to assume that these methods are correct merely because the man is a top performer. By the same token, the methods taught by the successful coach are often considered to be the last word because that particular coach has a winning team. Few seem to question or inquire into the methods or to consider the possibility that the star athlete or the championship team may be successful 'in spite' of the methods employed.

Muscle contractions depend upon temperature. In human beings, lowering the muscle temperature below normal decreases muscle irritability and work capacity (2, p. 21). On the other hand, during physical activity muscle temperature rises (3, p. 37). These two observations put together have

led to the practise of indiscriminate warming-up before athletic contests.

Physiologists know a number of good physiological reasons why warming-up should be beneficial. For example, Johnson writes (4, p. 150):

> There is currently some debate about the value of the 'warm-up' before athletic contests. It is easy to demonstrate that ten minutes of grade walking before the maximal oxygen test will increase the capacity to move oxygen to the muscles by five percent, thus increasing the endurance of the athlete.

It was not until 1953 that any doubt as to the validity of warming-up was apparent. At that time, Karpovich (5) issued the first challenge to the proponents of warm-ups. Since then the athletic world has been plagued with a multitude of conflicting evidence regarding the usefulness of present methods of warming-up. Some of these conflicts depend on the nature of the problem, and some on experimental design.

Karpovich and Hale (6) stated that there was no experimental evidence to prove that warm-up improves muscle function or reduces athletic injuries. This is fortified by other research workers who have recently challenged the values of warming-up prior to activity (7, 8, 9, 10, 11, 12).

By contrast, Morehouse and Miller (13) concluded that

performance improved if the muscles were slightly warmed-up first before the activity. This is supported in the conclusions of various experiments (14, 15, 16, 17, 18, 19, 20).

Malarecki (21) has shown that running time in a sixty metre race improved when a subject thought about performing warm-ups before a race rather than performing them physically. However, information on this study is incomplete, and therefore, cannot be considered conclusive.

Obviously, more research is needed to clarify the warm-up issue. Warm-up effects on accuracy have not been explored as extensively as the effects of a warm-up period on speed, strength and endurance.

The writer is particularly interested in basketball; therefore it was decided to investigate warm-up effects on accuracy in shooting free throws.

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CHAPTER III

REVIEW OF LITERATURE

The effects of warm-up on accuracy have not been explored as adequately as the relative effects of warm-up on speed and endurance. Lawther (1, p. 229) exemplifies this important area of physical performance.

> The principles of physiological efficiency mentioned earlier in connection with warming-up before competition are especially applicable to accuracy. One tunes up his physiological mechanisms, checks and puts a last minute touch to his motor patterns, and readjusts his perceptual habits to the somewhat different backgrounds. The muscles become more elastic and more ready, body flexibility is increased, and the skill patterns get a motor rehearsal that warms and activates the muscle patterns and removes any chance sluggishness or temporary resistance to performance.

Swegan and Thompson (2), as part of a comprehensive study, investigated warm-up effects on accuracy in basketball foul shooting. Their subjects, members of the Pennsylvannia State freshman basketball team, were tested under the conditions of warm-up and no-warm-up. The order of testing was completed on alternating days until each subject was tested three times under each condition.

Testing with a warm-up, prior to shooting his foul shots, each player warmed-up by (a) general floor shooting for ten minutes, (b) passing for three minutes, and (c) shooting ten foul shots. When being tested with no warm-up

each player shot the required twenty foul shots as soon as he arrived on the basketball court.

A critical ratio of 9.07 was obtained between the performance scores without preceeding warm-up and performance scores after a "formal" warm-up. This t - ratio was significant at the .01 level and indicated that warm-up was important for accuracy in foul shooting in basketball. More specifically, they concluded (3, p. 23).

> Formal warm-up in basketball foul shooting improved performance significantly.

A study made in 1947 by Skubic and Hodgkins (4) generally followed the procedure established by Swegan and Thompson. Thirteen women physical education majors were tested for accuracy as measured by the number of baskets they could make in ten free throws. Testing was carried on for a twelve week period with one testing day each week and all subjects being tested under identical conditions each session. Warm-up conditions were: (a) related warm-up - three free shots, (b) general warm-up - twelve jumping jacks and (c) no warm-up.

Analysis of various techniques were applied to the performance of the subjects to determine the effects of the three conditions on test scores for accuracy. They concluded (5, p. 150):

> There was no significant difference among the methods of warm-up. While not statistically significant, there was a tendency for higher scores to result on tests which followed a related warm-up. There was no significant difference among scores on different days, all scores tending to increase from day to day.

The present study parallels that done by Skubic and Hodgkins (6) in that it involves a related and unrelated warm-up separately. However, the related warm-up was extended to five free shots because it was felt that these were required to "fix in the athlete's neuromuscular coordinating system the exact nature of the impending task" (7, p. 30). This of course is an aribitrary selection.

In the same manner the present study involves astride jumping for one minute instead of twelve jumping jacks as an unrelated warm-up. It is questionable whether the twelve jumping jacks produced "warm-up" in the strictest sense, that is, increased the temperature of the muscles to any marked degree.

The comprehensive general warm-up used by Swegan and Thompson (8) combined both the related and unrelated warm-up methods. This is done very frequently in athletics and Karpovich (9) points out that jogging before a race is an excellent example of this. Specifically he states: (10, p. 15):

> Jogging done by a runner involves activity

> which will later be used in the contest. Therefore jogging contributes an element of formal (or related) warm-up.

However, in this case, jogging is done primarily as a general (or unrelated) warming-up. He continues (11, p.16):

> On the other hand, a pole vaulter or a broad jumper who makes preliminary runs does it not for the sake of general warming-up but to improve his skill by better pacing.

Related Studies

Many athletes use the overload method of warming-up prior to actual participation. The benefit of this type of warm-up was tested on Michigan State freshman baseball players by Van Huss, Albrecht and Nelson (12). Velocity and accuracy of throwing a baseball were determined after normal warm-up, using a regulation weight ball, and after warming-up with a heavier ball. Although the velocity was consistently greater after using the heavier ball, the accuracy was not significantly different.

Junior high school girls were chosen as subjects for Wittes (13) study comparing the effect of different warm-up intensities on the accuracy of throwing a softball. The subjects were classified as either skilled or unskilled performers and the accuracy measures were taken following five, ten, and twenty bouts of activity. The exercise bouts chosen for use were combinations of jumping jacks and distance

runs. Results from this experiment showed that (14, p. 308):

(a) there is no difference in the effect of light exercise as compared with moderate and heavy exercise on the throwing accuracy of either skilled or unskilled subjects.

(b) unskilled subjects show a higher degree of accuracy following exercise at each of the three levels of duration than they do following no exercise.

(c) skilled subjects show no change in accuracy following light and moderate exercise, but they show a decrease in accuracy following heavy exercise.

Thompson (15) reports on part of a study (16) which was carried out to investigate whether warm-up affected accuracy in typing and accuracy in bowling. He noted that the accuracy in these two particular activities were improved following a formal warm-up but he does not appear fully convinced as to their value. Succinctly, he says (17, p. 242):

> There is a wide variability in the effect of warm-up on individual performance. In other words, warm-up seems to help performance as measured by group averages but performance of certain individuals within the group may not be improved by warm-up preceding the performance.

Attitudes

It is generally accepted that attitude is an important

psychological factor affecting human behavior. According to Leuba (18, p. 118):

> Attitudes are behavorial predispositions which exert an enduring controlling influence over behavior.

Therefore, knowing an individual's attitude toward a subject helps one predict how he will do in a situation involving the subject. Smith and Bozymowski (19, p. 78) feel that the following two questions may be raised.

(a) Will favorable attitude toward warm-up affect performance preceded by a warm-up?

(b) Will an unfavorable attitude toward warm-up affect performance preceded by a warm-up?

For example, in a situation in which warm-ups precede physical performance, one might predict that those individuals who believe a warm-up period is necessary would be motivated to try harder when a warming-up period preceded performance. Likewise, those individuals who do not feel warming-up is necessary might not have this response.

With this particular thought in mind, Smith and Bozymowski (20) investigated the attitudes of college women toward warm-ups. These attitudes were then related to the affect of a warm-up prior to performance in an obstacle race. Results indicated that the subjects with a more favorable attitude toward warm-ups performed better when warm-ups

preceded the obstacle race.

Warner (21, p. 12) feels that in addition to the physiological values derived from a preliminary warming-up period, "a warm-up also serves to bring about psychological adjustments." He states that (22, p. 12):

> Muscular tension and nervousness experienced before the event are greatly reduced, thus allowing the mind to focus on the race at hand and prepare for it logically.

Massey, Johnson and Kramer (23) using hypnosis to control the psychological variable, demonstrated that performance after the two conditions, warm-up and no warm-up were about the same. The subjects were in a deep hypnotic state prior to all testing, and when tested they had no conscious awareness of whether they had or had not warmed-up.

Vertical jumping was found to improve in two separate experiments conducted by Pacheco (24, 25) when psychological control was secured by disguising the purpose of the tests. These results did not agree with those found by Merlino (26) who investigated the effect of massage on jumping performances. He tested college men after ten minutes of vigorous massage and after treatment with a psychological control device. Thirty-six subjects averaged 2.63% higher after treatment. The use of a psychological control device indicated that psychological factors can influence experimental results.

Psychological effects have often been discussed as the possible reason for differences between performance after warm-up and without warm-up.

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CHAPTER IV

METHODS AND PROCEDURES

The subjects selected for the study were ten members of the University of British Columbia Men's Senior Varsity Basketball Team. The more experienced members of the team were selected because it was anticipated that their superior ability would produce more consistent results. Prior to testing the players had completed four months of intensive training.

Testing took place on Tuesday, Wednesday and Thursday of each week and nine consecutive practices were utilized for testing purposes. Subjects were tested each of these days under similar enviornmental conditions such as: time of day, place, room lighting and atmosphere. Practices were not held on the other days of the week because of schedule commitments.

Ten free throw attempts were required for the accuracy test. Each player was tested a total of nine times, three times immediately after each of the following warm-up conditions:

Condition I: related warm-up

Condition II: unrelated warm-up

Condition III: no preliminary warm-up

To rule out the possibility of the learning factor influencing the results obtained, all players were not tested under the same warm-up conditions each day (Table I).

TABLE I

BALANCED TESTING DESIGN AS FOLLOWED BY EACH SUBJECT

	Conditions Each Testing Day								
Subjects	1	2	3	4	5	6	7	8	9
1	R	N	U	R	N	U	R	N	U
2	N	U	R	N	U	R	N	U	R
3	U	R	N	U	R	N	U	R	N
4	R	N	U	R	N	U	R	N	U
5	N	U	R	N	U	R	N	U	R
6	U	R	N	U	R	N	U	R	N
7	R	N	U	R	N	U	R	N	U
8	N	U	R	N	U	R	N	U	R
9	U	R	N	U	R	N	U	R	N
10	R	N	U	R	N	U	R	N	U

R - Related Warm-Up

N - No Preliminary Warm-Up

U - Unrelated Warm-Up

Subjects number one, four, seven and ten were tested under similar conditions each day throughout the experimental period. They alternated conditions each day beginning with a related warm-up on the first day, no preliminary warm-up on the second day and finally an unrelated warm-up on the third day. This rotation of conditions was repeated until each of these four players had been tested three times under each of the three conditions.

Subjects two, five and eight began with no preliminary warm-up on the first testing day, an unrelated warm-up on the second day and the related warm-up on the third day. Again this rotation of the three conditions was followed until they had been exposed to each of the three testing conditions three separate times.

Subjects three, six and nine began on the first day by shooting their ten test shots following an unrelated warm-up, the second day following an related warm-up and on the third day with no preliminary warming-up period.

Methods of Testing

Players were encouraged to use the method of shooting they usually employed for the basketball free throw and were instructed not to alter their shooting method during the entire experimental period. Each subject was able to shoot his ten free shots at a rate which best suited him and he shot at the same basket each time he was tested. The exact position the player selected for shooting could be maintained because he was provided with a "rebounder" who retrieved the ball after each shot and carefully passed it back to him. Whereas the players reported to the testing area at five minute intervals, the same person was able to do the rebounding for all players during the testing sessions. The investigator recorded all results on individual score sheets

(see Appendix B) and following each testing session recorded these scores on a master score sheet (see Appendix E).

Related Warm-Up

Players entered the gymnasium from the team dressing room and assumed their position for the basketball free throw. Five consecutive free shots were taken (with rebounder) as a preliminary warm-up and following these they took the ten free throws required for the test.

No Preliminary Warm-Up

Each subject immediately proceeded to shoot the ten free shots required for the test on entering the testing area from the dressing room. The only physical activity previous to testing was the walking from the changing room to the shooting position.

Unrelated Warm-Up

After entering the testing area the player did "astride jumps" for one minute at a rate of one complete astride jump per second. This timing was controlled by the experimenter with the aid of a large standard timing clock. Upon completion of the exercise the subject participated in the shooting test.

Definition of Astride Jump

This exercise is taken from J.G. Thulin (1) who calls it a "standing wide astride jump". The exercise involves the following.

(a) Starting Position:- Standing, feet together, heels touching and toes slightly apart, knees naturally straight and arms hanging straight at the sides.

(b) Astride:- Jump to a position in which both feet are moved equally far to either side. Legs straight, weight equally distributed on both feet which are separated approximately three foot-lengths apart. At the same time the arms swing outward and upward with hands clapping together overhead.

(c) To complete the exercise, reverse these movements to return to the original starting position.

At the completion of the testing the subjects were questioned individually in an attempt to determine their attitudes toward warming-up prior to shooting free throws. Secondly, each was asked to give what he would consider an adequate warm-up before taking part in the shooting test. Whereas this was not one of the main purposes of the study, a detailed account of the individual reactions was not kept.

The investigator attempted only to record trends in opinion and extreme deviations, if any.

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CHAPTER V

RESULTS

Ten members of the University of British Columbia Senior Men's Varsity Basketball team were involved in an experiment investigating different warm-up procedure influences on accuracy in shooting basketball free throws. Each player did the standardized basketball free throw test nine times - three times after no warm-up, three times after an unrelated warm-up and three times after a related warm-up. A balanced design was used in order to control the order in which the trials were carried out and thus eliminate bias due to 'learning effect'.

The statistical technique of "Planned Comparisons Among Means" (1) was applied to the obtained scores in order to test the statistical hypotheses.

Since the same subjects were tested under three different experimental conditions, it was possible to remove from the total variance that which arose from individual differences among the ten subjects. This was done in order to examine the differences among the warm-up conditions independently of differences among persons. In this respect there is a very intimate connection between analysis of variance and the technique of planned comparisons among means. The latter was chosen in this instance because this approach is particularly valuable when the researcher

> at the outset has a number of questions he wants to answer separately instead of planning to analyze his data to see if any over-all experimental effects exists (2, p. 460).

In this instance the particular questions to be answered will involve testing the following:

(1) There is no significant difference between performance following an unrelated warm-up and performance without a preliminary warm-up.

(2) Performance following a related warm-up will be better than performance following an unrelated warm-up or performance without a preliminary warm-up.

Table II shows the individual scores and total scores obtained by the group under each of the experimental conditions.

TABLE II

INDIVIDUAL SCORES AND TOTAL SCORES FOR EACH OF THE WARM-UP CONDITIONS

Subject	Related Warm-Up	No Warm-Up	Unrelated Warm-Up
1	21	20	21
2	21	24	22
3	28	24	21
4	20	19	18
5	27	20	25
6	25	21	24
7	25	21	23
8	21	18	20
9	25	21	22
10	25	29	27
Total	238	217	223

Note:- Individual totals for each condition constitute the number of successful free throws out of thirty attempts.

RESULTS OF STATISTICAL ANALYSIS

Unrelated Warm-Up Vs No Warm-Up

One of the hypothesis of the study was that skilled basketball players would demonstrate equal accuracy under conditions of no warm-up and unrelated warm-up. This was tested as:

Ho: $\mu N = \mu u$

H1: $\mu N \neq \mu u$

u = unrelated warm-up

N = no warm-up

A t of 0.67 was obtained for the above thus supporting the hypothesis of no difference between the effects of no warm-up and unrelated warm-up upon accuracy in free throw shooting. The probability of such a t in repeated tests would result in greater accuracy in a basketball free throw test than either an unrelated warm-up or no warm-up. Since it was demonstrated, with low probability of Type II error on being wrong, that there was no difference in accuracy performances under conditions of unrelated warm-up and no warm-up, it may be assumed that N = u. Under this assumption, the hypothesis to be tested was able to be expressed as follows:

Ho: μR = average ($\mu N + \mu u$)

or $2 \mu R = \mu N + \mu u$

H1: $\mu R >$ average ($\mu N + \mu u$)

or $2 \mu R > \mu N + \mu u$

u = unrelated warm-up

N = No warm-up

R = Related warm-up

The statistical analysis resulted in a t of 2.32 which was significant random sampling is less than .50. Acceptance of Ho then involves very small probability of a

Type II error, considered most serious in this case.

TABLE III

Statistical Analysis of the Hypothesis
Showing Data and Value of t

NULL HYPOTHESIS

Shooting Without a Warm-Up Will
Produce Results Comparable to
Shooting Following an
Unrelated Warm-Up

Conditions	Totals	T_1-T_2	Mean	Mean Sq. Residual	Deg. of Freedom	t
1. Unrelated Warm-Up	223	6	22.3	4.03	18	0.67
2. No Warm-Up	217		21.7			

For 18 degrees of freedom (2 tailed test) a t of 2.10 is significant at the 5 percent level of significance

Related Warm-Up Vs Unrelated Warm-Up: No Warm-Up

A second and principal hypothesis of the study was that a related warm-up at the .05 level of significance. It was possible therefore to reject the hypothesis of no difference between a related warm-up and either unrelated or no warm-up conditions and to accept the experimental evidence as supporting the hypothesis that the related warm-up would produce greater accuracy in the free throw test than either the unrelated warm-up or no warm-up.

TABLE IV

Statistical Analysis of the Hypothesis
Showing Data and Value of t

NULL HYPOTHESIS

Accuracy Following a Related Warm-Up Will
Be Comparable to Results Obtained
Following an Unrelated Warm-Up
or Shooting Without a Warm-Up.

Conditions	Totals	$T_1-\frac{(T_2+T_3)}{2}$	Means	Mean Sq. Residual	Deg. of Freedom	t
1. Related Warm-Up	238	18	23.8	4.03	18	2.32
2. Unrelated Warm-Up	223		22.3			
3. No Warm-Up	217		21.7			

For 18 degrees of freedom (1 tailed test) a t of 1.73 is significant at the 5 percent level of significance.

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CHAPTER VI

DISCUSSION

The foregoing analysis indicates that a related warm-up is superior to conditions of no warm-up or unrelated warm-up in contributing to shooting accuracy in a basketball free throw test. There was a slight tendency (not statistically significant) for an unrelated warm-up to be followed by better scores than shooting with no warm-up. A combination of the two elements, not necessarily as used in this study, might be desirable. Emphasis, however, should be on the related warm-up. The general warm-up used by Swegan and Thompson (1) is an example of what may be considered a combination of a related and unrelated warm-up. All three of the preliminary exercises were related to the game of basketball but only the free throw practice can be considered a related warm-up for a free throw accuracy test.

Comparing the demonstrated advantage from specific warm-up (or related practice) to the relatively limited advantage which has been shown in this experiment to accrue non-specific warm-up (unrelated), it is probably safe to suggest that preliminary warm-up should be specific in nature whenever possible, or to the extent possible. When specific warm-up is impracticable, then non-specific warm-up would often be preferable to no warm-up at all. However, it should be kept in mind that only a small number of subjects were used in this experiment and difficulty thus arises in

forming generalizations as to the bearing of these results upon a large population sample. Also, the three tests per warm-up method may not have been enough to allow for any true differences to result from the experimental conditions.

The findings of this study are partially in agreement with those of Skubic and Hodgkins (2) and partially contrary to them. In the present study it was found that a related warm-up resulted in significantly higher performance scores than did the unrelated warm-up or no warm-up while Skubic and Hodgkins found no differences among the three methods. However, the results of this study are in accord with Skubic and Hodgkin's finding that there was no significant difference between the unrelated warm-up effects on accuracy and shooting without a warming-up period. It might be noted that, although the purposes of the two studies being compared were very similar, the warm-up procedures used were somewhat different. Skubic and Hodgkin's light warm-up consisted of twelve jumping jacks for an unrelated preliminary exercise and only three practice free throws for the related activity. Both of these warm-ups were followed by five minutes rest before performance in the test which might give the body mechanisms ample opportunity to return to pre-warm-up condition thus eliminating any possible warm-up effects.

It might be postulated that a theory of neural facilitation could be responsible for the results obtained

in this experiment. This theory of warm-up which has not been fully stated in the literature, may be inferred from the experimental results and from the subjective experiences of the athletes. The theory contends that preliminary exercise may facilitate neural processes at either low or high levels, or both, of the nervous system.

Since most athletes warm-up by modified participation in the activity in which they are subsequently going to compete, it is possible that the advantage of warm-up can be explained primarily by referring to sensory, coordinating, and reflex phenomena. Accordingly, under this theory, matters of intramuscular temperature, internal resistance and circulatory efficiency might be relegated to an insignificant or secondary position, or they might be thought to influence neural efficiency rather than peripheral muscle efficiency.

Finally, under the heading of "neural facilitation", it may be suggested that the observed benefits of warm-up are subjective, "acting as a prevading prejudice which is psychologically reflected in performance. The facts that these benefits are only subjectively interpreted does not, of course, suggest that they are not real and effective. It means that a psychological mechanism has been substituted for peripheral physical and chemical mechanisms" (3, p. 68).

In the present stage of research, all this remains

mere speculation.

The subjective experiences of athletes indicate that performers have a desire, amounting to almost compulsion, to "get the feel" of their activity prior to competition. The advantage of this can be attributed to practice effects, "to reinforcement or verification of eye-to-muscle and proprioceptive sensory cues, and similar mechanisms" (4, p. 70).

Despite the fact that very little research has been done on "attitude and warm-up", the psychological implications of warming-up are reflected in performance and therefore warrant consideration. Subjectively, most athletes think that a warm-up will help them and consequently they feel better and more confident after this preliminary exercise. This fact in itself, dependent upon the individual, is likely to have a profound influence upon performance.

A suggestion has been made that the warm-up period gives the individual an opportunity to make certain adjustments before beginning participation in a competitive event. Griffith (5), Thorndike (6) and Warner (7) are among writers who propose that a warm-up is beneficial because during this time the performer can get the proper mental set and logically prepare for the contest which is to follow.

Beyond these explanations, due to the inseparable

relationship between mind and body, there are other more subtle psychological mechanisms which may operate during warm-up activities. For instance, it has been stated by several authorities that many of the physiological adjustments made during warm-up can be attributed to psychological stimulation (8, 9, 10, 11, 12).

In the present study all ten subjects felt that a warm-up was necessary for top performance in the accuracy test. Nine players picked the related warm-up to be the most useful of the conditions used. Seven of these nine players scored better following a related warm-up. One player in the group felt that he could shoot equally well under any of the conditions unless he was actually "cold". It was interesting to note that he followed this comment with a "but" clause indicating that warm-up was of value to him. At one point during the experimental period this player had scored forty-four consecutive free throws extending over 5 testing sessions and including all three of the warm-up conditions. His final results favored the no warm-up method, however, this must be considered a major deviation in the scores. In only one case did the unrelated warm-up result in greater accuracy than the related warm-up. Six of the players felt that the astride jumping actually "put them off" and it took a few shots to regain the needed shooting state.

If the related and unrelated warm-ups are averaged

together and compared to no warm-up results it can readily be seen that "total warm-up" was far superior to shooting with no warm-up. This indicates, perhaps, that because the players favored warming-up, this may have influenced the results. This would coincide with the findings of Smith and Bozyonowski (13) who found that the subjects with a more favorable attitudes toward warming-up did better when warm-up preceded an obstacle race than when no warm-up preceded the race. In the present study it is impossible to logically draw such a conclusion from the data whereas all players considered warm-up necessary.

There was general consensus that a "perfect" warm-up would consist of (a) general floor shooting and (b) practice free shots. Three players added "ball handling" to these others.

Table II, page 30, demonstrates the high degree of consistency displayed by the players involved in the experiment. Consistency in high levels of performance would serve to improve test reliability and to allow the demonstration of differences of smaller magnitude. In view of the scores displayed by the subjects, there is some indication that the majority of them were affected in a similar way by the three conditions that preceded the accuracy test.

When reference is made to particular methods of

warm-up, a related warm-up is generally advanced (14, 15, 16). This advice seems to be based on the belief that the "practice effect is in itself of value regardless of whether it is accompanied by physiological benefits" (17, p. 386). To the extent that the shooting test used in this study may be assumed to be representative of accuracy tests in general, it seems reasonable to conclude that unrelated warm-up has no significant effect upon accuracy as a performance factor. Practice effects, on the otherhand, are shown to exert an appreciable influence.

The results of this experiment pertain only to particular intensities and durations of particular kinds of warm-ups for a particular performance test. Therefore, it is not possible to define the optimal levels of intensity and duration for other situations. The determination of optimal degrees of intensity and duration for other situations must remain an important problem for further research and for trial-and-error experience in the specific practical situation.

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CHAPTER VII

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the relative effects of three chosen warm-up methods upon physical performance as measured by the basketball free throw. The test was taken a total of nine times by ten University men of high basketball playing ability, three times after each of the different warm-up methods. The experimental warm-up procedures used in this study were the following: (1) no warm-up, (2) an unrelated warm-up which was performed to generally activate the body systems at a non-fatiguing level, and (3) a related warm-up which resembled the movements to be used in the test itself. Test performances immediately followed the completion of the preliminary exercises. A systematic rotation in order was followed to balance out possible practice effects in favor of any of the warm-up methods. The raw scores resulting with each warm-up method were used for a statistical analysis and comparison.

In drawing conclusions from this study, it is necessary to recognize that they can be made only within the stated limitations of the experiment. On the basis of the data gathered and statistical treatment, the following results were evident:

(1) Related warm-up resulted in higher accuracy scores in basketball shooting than did warm-up conditions

of no warm-up or unrelated warm-up. (Statistically significant at the .05 level of significance).

2. There was no statistical significant difference in accuracy scores following an unrelated warm-up and scores made with no warm-up exercise. There was however, a slight tendency for scores to be higher following the unrelated warm-up.

In spite of the care taken in selecting the accuracy test, its use is subject to important limitations. Characteristically, a given skill yields rather low correlations with other skills (whereas strength scores, for example, tend to intercorrelate highly even when testing techniques and measuring devices are different). Although this shooting test undoubtedly depends strongly upon accuracy and precision, and to a negligible extent upon strength, speed of movement and endurance, it need not necessarily be considered a measure of a general factor of accuracy. On the otherhand, it is a typical accuracy test and it is logical to presume that warm-up might affect it in a typical way.

Implications of these conclusions for practical procedures in physical education and athletics would seem the the following:- (1) that it is worthwhile to execute preliminary exercises just prior to participation in basketball shooting because performance will be better than if no

warm-up precedes the activity, and (2) that best performances will occur when the warm-up is to be subsequently performed.

It is recommended that further studies in this area deal with the following problems:

(1) The effects of warming-up on other types of physical performance.

(2) The effects of varying the intensity, duration, and nature of warm-up activities.

(3) Possible relationship between warm-ups and athletic injuries.

(4) Specific physiological or psychological explanation of how warming-up affects the human organism.

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APPENDICES

APPENDIX A

STATISTICAL TREATMENT

The technique of planned comparisons among means was used to analyze the results in order to answer the particular questions the experimenter entertained before the collection of the data. Level of significance was required to reach 0.05 to be acceptable. To obtain the significance for each questions, the following procedure was used:

The data were tabled for a two-way classification with one entry per cell. Rows were individuals, and columns were treatments. The data relates to the same group of individuals tested under different treatment conditions.

TABLE 1

TABLE FOR TWO-WAY CLASSIFICATION
WITH ONE ENTRY PER CELL

Subjects	Related Warm-Up	No Warm-Up	Unrelated Warm-Up	Totals Tr.
1	T_{11}	T_{12}	T_{13}	$T_{1.}$
2	T_{21}	T_{22}	T_{23}	$T_{2.}$
3				
.				
.				
.				
10	$T_{10,1}$	$T_{10,2}$	$T_{10,3}$	$T_{10.}$
T.C	T.1	T.2	T.3	T

In Table I a simplified notation is used. The sum of all observations in the r^{th} row are denoted by $T_{r.}$, the sum of all the observations in the c^{th} column by $T_{.c}$, the sum of all the observations in the cell corresponding to the r^{th} row and the c^{th} column by T_{rc} and the sum of all N observations by T.

The sums of squares were obtained by applying the appropriate computation formulaes (1).

$$\text{Sum of squares - Rows (Between Individuals)} = \frac{1}{C}\sum_{r=1}^{R} T_{r.}^2 - \frac{T^2}{N}$$

$$\text{Sum of Squares - Columns (Between Warm-Up Conditions)} = \frac{1}{R}\sum_{c=1}^{C} T_{.c}^2 - \frac{T^2}{N}$$

$$\text{Sum of Squares - Interaction (Individuals by Conditions)} = \sum_{r=1}^{R}\sum_{c=1}^{C} x_{rc}^2 - \frac{1}{C}\sum_{r=1}^{R} T_{r.}^2 - \frac{1}{R}\sum_{c=1}^{C} T_{.c}^2 + \frac{T^2}{N}$$

$$\text{Sum of Squares - Total} = \sum_{r=1}^{R}\sum_{c=1}^{C} x_{rc}^2 - \frac{T^2}{N}$$

Source of Variation	Degrees of Freedom
Rows - Between Individuals	9
Columns - Between Warm-Up Methods	2
Interaction - Individuals by Warm-Up Methods	18
Total	29

N = 30

Error term = Mean Square Error = $\frac{\text{sum of Squares Interaction}}{\text{Degrees of Freedom Interaction}}$

$$t = \frac{\hat{\psi}}{\sqrt{\sum a^2 N \text{ (MS error)}}}$$

18 degrees of freedom
(degrees of freedom interaction)

$\hat{\psi}$ = the value of some particular population comparison

$\sum a^2$ = the sum of the squared weights that enter into the comparison $\hat{\psi}$.

REFERENCE

Ferguson, George A., Statistical Analysis in Psychology and Education, McGraw-Hill Book Company, Inc., New York, p. 253, 1959.

APPENDIX B

INDIVIDUAL SCORE SHEET

Subjects 1, 4, 7 and 10

Name _____

Address _____

Phone No. _____

Age _____

Testing Day	1	2	3	4	5	6	7	8	9
Successful Free Throws	R	N	U	R	N	U	R	N	U

R = Related Warm-Up

N = No Warm-Up

U = Unrelated Warm-Up

APPENDIX C

INDIVIDUAL SCORE SHEET

Subjects 2, 5 and 8

Name _____

Address _____

Phone No. _____

Age _____

Testing Day	1	2	3	4	5	6	7	8	9
Successful Free Throws	N	U	R	N	U	R	N	U	R

R = Related Warm-Up

N = No Warm-Up

U = Unrelated Warm-Up

APPENDIX D

INDIVIDUAL SCORE SHEET

Subjects 3, 6 and 9

Name _____

Address _____

Phone No. _____

Age _____

Testing Day	1	2	3	4	5	6	7	8	9
Successful Free Throws	U	R	N	U	R	N	U	R	N

R = Related Warm-Up

N = No Warm-Up

U = Unrelated Warm-Up

APPENDIX E

MASTER SCORE SHEET

Subject 1	R	N	U	R	N	U	R	N	U
2	N	U	R	N	U	R	N	U	R
3	U	R	N	U	R	N	U	R	N
4	R	N	U	R	N	U	R	N	U
5	N	U	R	N	U	R	N	U	R
6	U	R	N	U	R	N	U	R	N
7	R	N	U	R	N	U	R	N	U
8	N	U	R	N	U	R	N	U	R
9	U	R	N	U	R	N	U	R	N
10	R	N	U	R	N	U	R	N	U

R = Related Warm-Up

N = No Warm-Up

U = Unrelated Warm-Up

APPENDIX F

RAW SCORES

Subject																							
	1	7	R	7	N	6	U	9	R	7	N	7	U	5	R	6	N	8	U
	2	9	N	8	U	6	R	5	N	8	U	7	R	10	N	6	U	8	R
	3	6	U	10	R	7	N	8	U	9	R	9	N	7	U	9	R	8	N
	4	8	R	6	N	5	U	5	R	6	N	7	U	7	R	7	N	6	U
	5	7	N	9	U	8	R	7	N	6	U	9	R	6	N	10	U	10	R
	6	7	U	9	R	6	N	9	U	7	R	8	N	8	U	9	R	7	N
	7	9	R	7	N	7	U	7	R	7	N	10	U	9	R	7	N	6	U
	8	5	N	6	U	5	R	6	N	7	U	7	R	7	N	7	U	9	R
	9	5	U	8	R	10	N	7	U	9	R	5	N	10	U	8	R	6	N
	10	7	R	10	N	10	U	8	R	9	N	9	U	10	R	10	N	8	U

R = Related Warm-Up

N = No Warm-Up

U = Unrelated Warm-Up