RELATIONSHIPS BETWEEN WARM-UPS AND PHYSICAL PERFORMANCE

by

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CHAPTER I

INTRODUCTION

Until quite recently, a belief in the value of warming up prior to participation in strenuous physical activity was accepted without serious question by almost all physical educators, exercise physiologists, athletes, and others concerned with the optimum performance and welfare of participants in athletic activities. Consequently the execution of preliminary exercises of some kind before participating in vigorous physical activity is a common practice, particularly in competitive sports.

Warming up has traditionally been practiced in accordance with beliefs that it results in improved performance and aids in the prevention of injury during physical exertion. While several explanations and theories have been advanced in support of this procedure, there are others which question the worth of warming up.

Despite the fact that an abundance of literature could be found to theoretically describe the effects of warming up, until recent years very few experimental studies had been undertaken in an attempt to objectively determine the relative effects of various warm-up methods. A comparison of the results obtained in studies on this subject supplies varied and, in some cases, conflicting evidence; therefore, considerable discussion has been aroused and some doubts have been raised concerning the integrity of present practices regarding warm-ups.

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It would seem to be of utmost importance and practical value for

physical educators to know whether or not there is any worth in warming up just prior to strenuous physical activity. One important aspect of this basic question can be answered by determining whether or not physical performance is improved by warming up. Due to the controversial implications of the results of completed studies concerning relationships between warm-ups and physical performance, there seems to be a need for further research in this area.

Statement of Problem

The purpose of this study was to determine and compare the relative effects of three warm-up procedures upon physical performance as measured by selected objective basketball skill tests.

The three warm-up procedures used in this study were: 1) no warm-up, 2) an unrelated warm-up which was performed to generally activate the body systems at a nonfatiguing level, and 3) related warm-ups which involved movements similar to those required in the actual test activities.

The measures of physical performance used to evaluate basketball playing ability were the following tests: 1) Scott's Passing Test, 2) Jones' Half Minute Shooting Test, and 3) Scott's Jump and Reach Test.

Each test was taken nine times by nineteen college women of relatively high basketball skill. The warm-ups directly preceded testing, and the order in which the three methods were used followed a systematic rotation in the administration of each test. The recorded results were statistically analyzed and comparisons were made.

CHAPTER II

REVIEW OF LITERATURE

General Explanations and Opinions Concerning Warm-Ups

A review of textbook descriptions of the effects of warm-up activities upon an individual's well-being and performance would lead one to believe, perhaps falsely, that there is scarcely reason to question the value of this practice.

Literature in the field of physical education seems to unanimously advocate warming up as not only desirable but essential for optimum safety and performance in vigorous physical activity. Apparently representative of physical educators' written beliefs concerning the place of the warm-up in activity programs are the following statements:

> The warm-up is essential to all sports and should be taught. (22, p. 162)

> Warm-up activities serve a useful purpose. . . . In brief, they give tone to the body. . . . Improper attention to warm-up activities accounts for many of the strains and more serious injuries suffered by participants in active games and sports. (3, p. 54)

> There is one thing common to all sports, and that is the importance of an athlete being properly 'warmed up' before participation. (28, p. 16)

> Warming-up improves performance and prevents injury in vigorous activities. . . . (20, p. 30)

> Before undertaking any strenuous exercise the participant should warm up thoroughly. . . . A good warm-up is necessary if the muscles are to function efficiently and injury is to be avoided. (8, p. 186)

In substantiating the contention that warming up is beneficial, most physical education literature has drawn largely upon the statements of physiologists concerning the effects of exercise upon the body

systems. The practice of warming up has also been justified by making reference to favorable effects derived through practice, psychological adjustments, and the production of a feeling of general well-being which is said to be experienced by the participant.

From a review of their writings, most physical educators seem to believe that warming up prior to strenuous activity, particularly activity of competitive nature, is essential to the physical, mental, and emotional readiness of the performer.

In reviewing literature in the fields of physiology and kinesiology, some questions are raised; but the majority of writers advise warming up before an all-out effort and state that it is essential to the achievement of best performance and the prevention of injuries.

To cite some general statements from textbooks which directly advocate warming up to improve performance, the following seem to be representative:

> . . . it is a matter of common practical knowledge that athletes are capable of better performance if they go through the process of warming up. (9, p. 388)

> Warming up is . . . important. Proper exercise increases the capacity of the organism to perform work. (15, p. 285)

> Performance is improved if the muscles have been slightly warmed up just before the activity. (19, p. 27)

> It has been demonstrated that preliminary warming up improves performance in athletic contests. (31, p. 107)

However, warming up is not universally advocated. Perhaps the greatest doubts have been raised by Karpovich (11) who questions the physiological values of warming up in regard to both the improvement of performance and the prevention of injuries. Rasch and Burke (23, p. 385),

while stating that "warm-up benefits to performances have been demonstrated in a sufficient number of experiments to warrant the tentative conclusion that preliminary exercise often improves subsequent maximal performance," also note that evidence on the value of this procedure is confusing and suggest that "the benefits of warm-up, when they have been detected at all, are inclined to be smaller in magnitude than has generally been assumed by athletes, coaches, and physiologists."

There are many theories of warm-up associated with the activation of physiological mechanisms and resultant implications of body readiness for and efficiency in physical performance. Most commonly discussed in attempting to physiologically justify the practice of warming up are the beneficial effects attributed to this process through the following phenomena: treppe in muscles, decreased muscle viscosity, increased muscle tone, circulatory and respiratory adjustments, chemical reactions involving necessary energy supplies, activation of neuromuscular processes, and stimulation of keener kinesthetic awareness.

The majority of writers cite the above effects as results of warming up and credit them with the improvement of physical performance; however, some of these explanations have been seriously questioned. For this reason these phenomena, along with other mechanisms which are associated with warming up, will be briefly discussed.

Specific Explanations and Theories of Warm-up

Much discussion leading to specific theories of warm-up is based upon proposed relationships between body temperature and physical performance. Available evidence seems to indicate that, within certain

limits, a body temperature which is higher than normal aids an individual in performing with optimum efficiency. Kleitman and Jackson (54) found that performance was best at times in the diurnal cycle when body temperature was highest. Asmussen and Boje (33) and Muido (59) demonstrated that active warm-ups produced rises in body and muscle temperatures and concluded that a higher temperature resulted in better performance.

Several writers (7; 9; 14; 19; 20; 24) have suggested that there is a temperature slightly above normal which is most favorable for muscular efficiency, and many explanations have been advanced to support the idea that an increase in temperature brought about by warming up is directly responsible for an increased work capacity in the organism. While Dawson (7, p. 681) states that the most obvious effect of heat production from muscular activity is an increase in ability to perform work with freedom from a feeling of distress; Asmussen and Boje (33), Gould and Dye (9), Lipovetz (14), Morehouse and Miller (19), Scott (26), and Zoethout and Tuttle (31) all credit this rise in temperature with the more specific function of increasing the rapidity and force of muscular contraction. Gould and Dye (9), Morehouse and Rasch (20), Lipovetz (14), and Thorndike (29) further point out that a rise in temperature facilitates biochemical reactions which supply energy for muscular contraction. This explanation received experimental support from Asmussen and Boje (33) and Burke (72) who reported that their results were in agreement with the theory that warming up increases deep local muscle temperature, thus resulting in a greater speed of energy yielding chemical reactions.

In opposition to the preceding explanations concerning the

effects of increased temperature upon muscular efficiency, however, Karpovich maintains that they are not sufficiently verified in the results of studies on warm-ups and physical performance and makes the following statements:

> In human beings, lowering of the muscle temperature below normal decreases muscle irritability and work capacity. On the other hand, during physical activity muscle temperature rises. These two observations put together have led to the practice of indiscriminate warming-up before athletic contests. (11, p. 14)

The treppe or staircase phenomenon in muscle is one of the factors most often mentioned in physiologically justifying the practice of warming up; however, it is subject to some question. Bowen and Stone (1), Bresnahan, Tuttle and Cretzmeyer (2), Gould and Dye (9), Morehouse and Miller (19), Riedman (24), Scott (26), and Wells (30) are among the writers who credit the attainment of a maximal response through the treppe effect with the beneficial result of more rapid, forceful, and effective muscular contraction when post warm-up activity is begun.

On the other hand, Karpovich (11, p. 16) states that the treppe phenomenon is not really of practical consideration since athletes do not commonly begin activity with fresh or rested muscles and since the staircase improvement is attained in a fraction of a second during the initiation of activity anyway. Rasch and Burke (23, p. 75) concur with this reasoning.

Another oft-quoted physiological explanation is based upon the belief that muscular efficiency is increased as muscle viscosity is decreased. Asmussen and Boje (33), Gould and Dye (9), Morehouse and Cooper (18), Morehouse and Miller (19), Riedman (24), and Wells (30) are some of the writers who state that the process of warming up is valuable

because it results in overcoming the internal resistance in muscles, thus enhancing the effectiveness of contraction.

While the fact that physical exercise tends to decrease muscle viscosity seems to be commonly accepted, there is some debate concerning the actual importance of this in regard to physical performance. Fenn, Brody and Petrilli (45), in a study concerned with tension during muscular contraction, noted that muscles do experience some difficulty in rapidly shortening against their own internal viscosity, but they also suggested that perhaps the importance of viscosity had been somewhat overestimated. Burke (72, p. 134) observed that his experimental results neither supported nor directly contradicted the viscosity theory.

It is contended by several writers (5; 6; 9; 14; 19; 20; 29; 31) that warming up promotes more efficient muscular work by increasing the velocity of metabolic activities and thereby adding to the effectiveness of adjustments which prepare the body for further activity. Metabolic advantages of the activity and accompanying rise of temperature involved in warming up are said to be increased efficiency in supplying the muscles with necessary food and oxygen and in removing waste products. Among the adjustments often cited in explaining this increased efficiency are the following: improved circulation throughout the body due largely to an increased rate and stroke volume of the heart, an increased blood supply to working muscles brought about by this improved circulation and by dilation of capillaries in the muscles, an increase in the respiratory rate and volume, easier separation of oxygen from hemoglobin, increased lung ventilation, and more rapid diffusion of gases.

That the aforementioned adjustments do commonly occur during physical activity of sufficient intensity and duration and that they are conducive to body efficiency are generally accepted facts. However, since these adjustments normally take place relatively quickly and easily when activity is begun, a question is raised concerning whether or not warming up produces necessary and/or significant beneficial effects in mobilizing the body for greater and more efficient activity. Nielsen and Hansen, as cited by Muido (59, p. 107), found that after heavy preliminary work more oxygen could be taken up in a final spurt than when the same work was begun from a resting condition; and they credited this effect to the increased circulation rate reached in the warm-up. Muido (59) concluded from his study that it was probable that a higher blood temperature, brought about by warming up, resulted in improved performance due to an increase in the velocity of circulatory and metabolic reactions. Contrary to these findings, however, Asmussen and Boje (33) and later Burke (72) reported that their experimental results did not support theories of important warm-up benefits due to increased circulation and respiration.

Some theories of warm-up are based upon the premise that the physical activity and practice involved in warming up promote skillful performance through the improvement of neuromuscular coordination. It is generally recognized that neuromuscular coordination is important to the achievement of optimum physical performance with a minimum of effort. Some reasons commonly given in explaining this are that relaxation of antagonistic muscles takes place more readily, that wasted effort is minimized by limiting movements to those necessary to the activity, and

that timing, accuracy and other factors essential to skilled performance are enhanced with improved neuromuscular coordination. The suggestion that neuromuscular coordination is improved by warming up is often explained in terms of neural facilitation, increased readiness of the muscles to respond quickly to nervous impulses, and the effects of the practice involved in related warm-ups.

Some writers (5; 6; 9; 18; 24; 28; 34) maintain that physical exercise activates the nervous system, making it more effective and thus favorably influencing the following performance. In discussing this theory, Burke (72) recognized that observed benefits in this area were mainly subjective but that this fact did not mean that they were not real and effective. He concluded that "the idea that warm-up may produce various kinds of neural facilitation is a pertinent, but relatively unexplored, theory." (72, p. 29)

Another proposal concerning relationships between warm-ups and coordination is that exercise stimulates the muscles so that they are more effective in receiving and responding to nervous impulses. (2, p. 33; 9, p. 97; 31, p. 102)

Morehouse and Miller (19) are among the writers who state that a related warm-up improves neuromuscular coordination and enables more skillful performance because it entails a rehearsal of the activity to be performed. Griffith (10, p. 190) also suggests that a related warm-up is valuable because "a skill is not often in its most useful condition until after it has been exercised for a few moments."

Some psychologists, as well as physical educators and physiologists, seem to feel that learning and performance are improved by the

practice involved in warming up. In studies concerned with motor and psychomotor learning, Adams (32), Bell (35), and Renshaw (80) have noted the effects of warming up. They state, generally, that this initial rise or spurt in performance (warm-up) is necessary in order for the learner to regain his stride after a period of rest.

An important factor involved in practicing is getting the "feel" of the activity and in some cases the implement to be used in it. Kinesthetic sense is recognized to be of definite importance in learning skills and in successfully repeating them thereafter. Because the proprioceptors located in muscles, tendons and joints are stimulated by muscular contraction and thus by movement itself, physical activity contributes to kinesthetic awareness. (26, p. 84) This has led to the suggestion that warming up prepares the body for efficient performance by increasing an individual's awareness of what the movement feels like. (20, p. 30) Burke (72, p. 27) suggests that advantages of an athlete getting the feel of the tools and the activity prior to competition can be attributed to practice effects, reinforcement or verification of eye-to-muscle and proprioceptive sensory cues and similar mechanisms.

Burke's discussion of the preceding theories is particularly pertinent, and he contributed the following thoughts on this subject:

> Since most athletes warm-up by modified participation in the activities in which they are subsequently going to compete, it might be postulated that the advantages 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 functions rather than peripheral muscle efficiency. At present this is speculation. (72, pp. 27 and 28)

In accord with many of the preceding theories concerning the effects of physical activity upon muscular contraction and coordination, the majority of textbooks credit the warming up process with an important function in preventing various discomforts and injuries sometimes sustained from athletic activities. Although this study is not directly concerned with this topic, it seems logical that such relationships between warm-ups and the optimum physical condition of athletes, if they do exist, might appreciably affect the quality of physical performance.

While some writers state that warming up reduces the likelihood of muscle contractures or muscle soreness (2; 9; 15; 20), the idea most often stressed is that an insufficient warm-up before an all-out effort is often responsible for such injuries as torn muscles and tendons. (5; 9; 19; 30) In connection with this, it has been suggested that warming up provides exercise to stretch tight muscles and ligaments, thereby increasing tissue elasticity and flexibility. This process in turn has been credited with the improvement of performance and the reduction of injuries. Lukes (77) found that warm-up exercises did increase the range of motion of the joints in the body; however, his experimental results provided no information concerning relationships between this and performance or injury.

Rasch and Burke (23, p. 386) pointed out that although a belief on the part of most coaches and athletes that warming up results in a decrease in injuries is based upon empirical experience, the idea can not be lightly discarded. Karpovich and Hale (53, p. 1117) were apparently correct in summing up available research information on this subject as follows: "To our knowledge, no objective evidence has been

presented that warming-up reduces the number of athletic injuries."

Despite the fact that very little research, if any, has been undertaken on the topic, 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 necessary psychological and emotional adjustments before beginning participation in a competitive event. Griffith (10), Thorndike (29), and Warner (70) are among the writers who propose that a warm-up is beneficial because during this time the performer can get the proper mental set for the contest which is to follow.

Beyond these explanations, due to the inseparable relationship between mind and body, there are other 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 the warm-up can be attributed largely to psychological stimulation. (6; 9; 29; 31; 43)

In summary, although there is not complete unity on the subject, most writers state that warming up yields various beneficial psychological and physiological adjustments which result in improved performance and reduced injuries; therefore they recommend that strenuous physical activity be preceded by a warm-up period which is appropriate for the

individual and the activity.

When reference is made to particular methods of warm-up, a related warm-up is generally advocated. (10; 20; 53) This advice seems to be based upon the belief that "the practice effect is in itself of value regardless of whether it is accompanied by physiological benefits." (23, p. 386)

Literature which does not support theories of important benefits derived through warming up, nevertheless, recommends continuing this practice until more conclusive evidence is found.

Experimental Studies

Several studies have been conducted in an effort to determine the relative effects of different warm-up methods upon various types of physical performance; however, it is difficult to draw definite conclusions from a comparison of their results.

One of the first experimental studies pertinent to relationships between warm-ups and physical performance was conducted by Asmussen and Boje (33). Their purpose was to find out whether a higher body temperature, brought about by active and passive warming up, resulted in a measurable beneficial effect upon physical performances. Using four adult male subjects of varying athletic ability, work capacity was measured by the time it took to complete designated performances on a bicycle ergometer. Comparisons were made of the results obtained after thirty minutes of rest and after an active warm-up which consisted of thirty minutes of preliminary work on the ergometer. From a series of experiments, Asmussen and Boje concluded that warming up was responsible

for significantly improved performance in both sprint and endurance rides on the bicycle ergometer.

Two of the subjects participated in a series of subexperiments which Asmussen and Boje conducted in order to see the effects of a higher temperature upon peak efforts such as those used in throwing or jumping. Using the same warm-up procedures described above, the maximum push that could be exerted by the calf muscles was measured by dynamometers and flexion of the elbow was measured with Hill's fly wheel. A comparison of performances after rest and after the active warm-ups led to the following conclusions: the calf muscles showed a measurable rise in temperature due to the preliminary work and therefore their strength increased through warming up; but the arm muscles did not rise in temperature and showed no significant improvement in strength due to warming up.

Although Asmussen and Boje reported that the study was carefully controlled and the results highly significant, it should be noted that Burke (72, p. 39) suggested that this work might be questioned on these bases: the exceptionally small number of subjects, insufficient psychological controls, and a lack of statistical evaluation of the data.

Burke (72) studied the relative effects of no warm-up and an unrelated warm-up upon performances dependent upon strength, speed of movement, endurance, and accuracy. Seventy-two untrained college men served as subjects in the following parts of the study: 1) the strength test which was a maximum contraction of the knee flexors as measured with a cable tensiometer, 2) the endurance test as measured by Carlson's Fatigue Curve, and 3) the speed of movement test which was the number of

right foot placements which could be made while running in place for ten seconds. Thirty-four untrained male subjects took the accuracy test which involved the propulsion of wooden disks along the floor by a push with the dominant foot.

The warm-up consisted of bench-stepping, with the cadences of stepping and the time intervals varied to give nine different combinations of intensity and duration - the longest warm-up lasting eight minutes and the shortest being two minutes. In each of the four subexperiments the subjects took the test once after five minutes of rest and once after a designated warm-up followed by a five minute rest period. The order of the warm-up methods and test administrations was controlled to equalize possible practice effects. After statistically analyzing differences in the results obtained with and without warm-ups, Burke concluded that optimal combinations of intensity and duration of warm-ups significantly enhanced muscular strength, but the kinds of warm-up employed in the experiment did not significantly influence speed of movement, endurance, or accuracy. Further, he concluded:

> Warm-up procedures on the part of . . . athletes appear to be justified whenever there is an important strength factor in the work to be done, if ease of performance or peak effort are objectives. The advantage of warm-up to the strength factor should also appear in any activity which demands important amounts of power or acceleration, because strength is related geometrically to speed in the production of power and acceleration.
>
> Specific warm-up (identical with preliminary practice) is preferable to nonspecific warm-up, provided that suitable intensities and durations are employed. Under these conditions, specific warm-up would activate the limited benefits shown in this experiment to accrue from nonspecific warm-up, and would additionally include the well-known benefits of pure practice. (72, pp. 136 and 137)

The purpose of Oliver's study (78) was to determine the effect of

an unrelated warm-up upon the performances of twenty-six junior high school boys in the following tests of physical abilities: 1) a timed zigzag run selected to test speed and agility, 2) a standing broad jump to assess power, 3) a softball throw for distance also used to test power, and 4) a back lift, as measured by a dynamometer, to determine strength. The subjects, who were divided into two sections for controlled order in warm-up methods and test administration, performed each test once without a warm-up and once with a warm-up which involved a series of calisthenic exercises and was begun approximately three minutes before testing. From a statistical analysis, Oliver found that mean scores for the standing broad jump and the back lift were significantly greater when these events were preceded by a warm-up; however, the mean scores for the softball throw and the zigzag run were not significantly influenced by this preliminary exercise.

In two studies pertaining to the effects of unrelated warm-ups upon performance in tests of physical abilities which were cited by Oliver (78), Buxton conducted an experiment with 1,057 Iowa school children between the ages of six and fifteen and concluded that a warm-up improved muscular fitness scores, and Dohrmann found that strenuous activity involving the lower extremities increased the strength of the hands and arms of ninety adult males.

Blank (36) randomly divided sixteen experienced track and field athletes into two groups and timed them in the 120-yard dash for twenty-two consecutive days. One group participated in dashes following an optimum warm-up while the other group ran after a minimum amount of activity, and the warm-up patterns were exchanged on alternate days. In a

second experiment, thirty-eight individuals who had no prior track and field experience followed the same alternating pattern before timed runs of 100 yards. In both cases, the mean difference in results after an optimum warm-up and after a minimum of activity was highly significant in favor of warming up. Blank concluded that a warm-up was beneficial to sprinting performance and that, for the groups tested, there was no apparent difference between the effect of warm-up routines upon experienced and inexperienced subjects.

Hipple (50) conducted a study on warm-up and fatigue in sprints. Ten junior high school boys, paired according to ability, ran five successive 50-yard races with a rest of approximately five minutes after each run. It was found that the first race had no beneficial effect on the second race, and the cumulative warm-up of the first and second races had no beneficial effect on the third race. It was reported that the fourth and fifth races were a little slower due to fatigue. Considering previous dashes as a warm-up for following trials, Hipple concluded that warming up did not improve sprinting performance.

In reviewing Hipple's study, Burke (72), Carlile (37), and Pacheo (60) suggested that the warm-up used might not represent an effective method, and Carlile further questioned the five minute wait between runs.

Karpovich and Hale (53) carried out a series of experiments to compare the effects of different methods of warming up upon physical performance. In the first experiment, the time required for seven college men track athletes to run 440 yards was recorded after three methods of warm-up. Following a rotation in methods, each subject per-

formed a total of sixty test runs - twenty after five minutes of deep massage, twenty after five minutes of digital stroking, and twenty after about ten minutes of preliminary exercise which consisted of jogging, calisthenics, and short sprints. A statistical analysis of the results showed no significant difference in the running times.

In a second experiment, five highly trained varsity and freshman track athletes were timed four times in the 440-yard run - twice without a warm-up and twice after digital stroking. Once again no significant difference was found in the results obtained with these methods.

In the final experiment, three highly trained male subjects performed twenty-four sprint rides on a bicycle ergometer. Twelve of the rides were performed after a warm-up of five minutes of preliminary work on the bicycle ergometer, and the other twelve were performed without a warm-up. It was found, contrary to the results of Asmussen and Boje in a similar experiment, that preliminary exercise did not improve sprint rides on the bicycle ergometer.

Kaufmann (75) conducted an experiment to determine the effects of warm-up and recovery techniques upon performances in successive running trials. On three different days, fifteen high school boys who were members of the varsity track team were timed in three 300-yard dashes and followed a designated procedure during the twenty minute interval between trials. In all cases the first run was preceded by a standard warm-up which consisted of about three minutes of jogging and calisthenics. The preparation methods used during the intervals between the first and second and between the second and third trials were the following: 1) rest, 2) seventeen minutes of rest followed by the

standard warm-up, and 3) recovery techniques for seventeen minutes, followed by the standard warm-up. The subjects were divided into three groups and followed separate orders in using a different method each day. From an analysis of data, a significant difference was found between the first and third trial times in favor of the combination recovery technique-warm-up method over the absence of warm-up. All other differences were statistically insignificant.

Matthews and Snyder (56) undertook a study to ascertain the effects of physical warm-up on the running time of fifty high school boys of limited track experience in the 440-yard dash. The warm-up consisted of alternate jogging and walking for 440-yards, calisthenics, and a few short sprints, and was followed by five to ten minutes of rest before performance in the dash. Over a sixteen day test period, each subject alternated daily between warming up and not warming up. After making statistical comparisons of the results obtained, it was concluded that warming up prior to performing the 440-yard dash had no significant effect in improving running time.

Raines (79) measured the performance of fifteen college men, by the number of steps which they could take in a thirty second period of time, after three different preliminary procedures in order to determine the relative effects of these experimental methods. The purpose of the first part of the study was to find for each individual the warm-up time which would result in his best all-out performance. The warm-up, which consisted of rhythmical step-ups on a small stool, was progressively increased by one minute until each individual's optimum warm-up time was determined. The second part of the experiment was to note the effect of

applying a cold pack to the subject's abdomen for a ten minute period half an hour before he performed his optimum warm-up. In the third part of the study, a hot shower was taken in place of the subject's optimum warm-up. Raines concluded from an analysis of data that an optimum warm-up alone resulted in better performance than either of the other preliminary procedures. It was further reported that the mean optimum length of warm-up was 6.6 minutes but that there was a wide variation between individuals.

Schmid, as cited by Michael, Skubic and Rochelle (57), found that both active and passive methods of warming up were beneficial to performance in swimming 50 meters, running 100 meters, and riding a bicycle. It was further concluded that the most effective active warm-up method was a related warm-up which involved the same motions as those used in the actual performance.

Sills and O'Riley (64) investigated the relative effects of rest, exercise, and cold applications in respect to performance. After warming up by jogging around an indoor track for five minutes, eighteen college men performed five bouts of spot-running with ten second intervals between bouts. After the initial five bouts the subject either rested supinely for eight minutes, walked and jogged for ten minutes, or was sprayed with cold water on the abdomen for eight minutes; then a second five bouts of spot-running were performed. The subjects were divided into three groups and followed a rotation in methods during a total of six days of testing. On the basis of the results recorded, it was concluded that physical performance as measured by spot-running was improved more by cold applications than by either rest or exercise, and

more by rest than exercise.

Simonson, Teslenko and Gorkin, as cited by Michael, Skubic and Rochelle (57, p. 357), found that preliminary exercise decreased the time required to run 100 meters by an average of seven per cent in a study involving seven subjects.

Lotter (55) studied the effects of fatigue and warm-up on speed of arm movements in tests of four minutes duration. Twenty college men were divided into two groups which followed different experimental procedures. Each group was tested twice - once after the control condition which was no warm-up and once after a designated active warm-up. The active warm-up for one group was four minutes of stationary running while simultaneously rotating both arms in a complete circle and this was followed by two minutes of rest; the other group performed two minutes of this same activity for their active warm-up. Within each group, half of the subjects performed first after no warm-up and then after the active warm-up while the other half followed the reverse order. In comparing these two active warm-up methods to the control condition, it was concluded that warm-up exercises were without effect under the conditions of this experiment.

Swegan, Yankosky and Williams (66) investigated the effect of repetition upon the speed of movement for preferred-arm extension as measured by an electrical timing device. Thirty college men participated in the two phases of this experiment. The first phase involved nineteen subjects on twenty repetitions, and the second phase tested eleven subjects on fifty repetitions. For purposes of this study, any test trial was considered a repetition and hence a part of the warm-up

for successive trials. Although it was noted that individuals varied considerably in successive repetitions, repeated trials resulted in faster movement times in all subjects and fifty trials produced faster movements than twenty.

Muido (59) undertook a series of experiments to determine the effects of active and passive warm-ups upon the swimming performance of three men. Active warm-up methods, which were followed by about ten minutes of rest, included ten minutes of jogging before 50 meter swims and ten minutes of work on a stationary bicycle prior to 200 and 400 meter swims. The control condition was fifteen to twenty minutes of rest. It was found from a comparison of results that in all cases a warm-up resulted in swimming a given distance in a shorter time than when no warm-up was performed.

DeVries (40) conducted an experiment to determine the relative values of warm-up procedures customarily used by competitive swimmers. Thirteen highly skilled competitive male swimmers of college age were divided into five groups on the basis of their swimming events. Following an order of rotation, each subject swam three 100-yard time trials with no warm-up and three 100-yard time trials immediately after each of the following warm-up methods: 500 yards of slow and continuous swimming, a six minute hot shower, a routine of calisthenics, and ten minutes of massage. It was found that the group as a whole showed significant improvement only following the swimming warm-up. DeVries further noted that there seems to be an interaction between the warm-up procedure and the type of stroke performed and suggested that it might be well to vary warm-ups accordingly.

Skubic and Hodgkins (65) investigated the effects of light warm-up activities on speed, strength and accuracy of thirty-one college women physical education majors. The subjects were randomly divided into three groups according to test activities and all followed the same general procedure. In an order of systematic rotation, they were tested four times after a five minute rest period, four times after an unrelated warm-up consisting of twelve jumping jacks, and four times following a warm-up of activity related to the actual test. Eight subjects were tested for speed by timed rides of one tenth mile on a bicycle ergometer. The related warm-up for this activity was a preliminary ride of eight revolutions at a moderate speed. Nine subjects participated in the softball throw for distance which was selected to measure strength. The related warm-up for this was five overhand throws to a partner at a distance of thirty feet. Thirteen subjects were tested for accuracy in ten basketball free throws and performed three free throws prior to the test when the related warm-up was used. From the results obtained, it was concluded that neither the presence nor absence of light warm-ups of short duration significantly affected performance on any of these tests. However, it was stated that, although not statistically significant, there was a slight tendency toward better scores shown in tests which were preceded by related warm-ups. Pacheo (61), and Michael, Skubic and Rochelle (57, p. 358), in discussing the absence of positive results in Skubic and Hodgkins' experiment, suggested that perhaps this could be explained by the fact that the warm-ups were neither strenuous in nature nor long in duration.

Michael, Skubic and Rochelle (57) studied the relative effects of

no warm-up, an unrelated warm-up, and a related warm-up upon the ability of seventy-seven college men to throw a softball for distance. The subjects were divided into three groups with the sequence of warm-up methods, which preceded the test of three throws for distance, alternated on different days. The unrelated warm-up consisted of a five minute period of calisthenics and sprint running. The related warm-up involved five minutes of playing catch with a softball, progressing at minute intervals from a distance of 25 feet to 50, 75, and 100 feet and finally to the farthest distance the subjects could throw. After retesting to establish reliability, an analysis of the average scores obtained with each of the three methods showed that both types of warm-ups resulted in significantly longer throws than when no warm-up was used and that there was no significant difference between the two types of warm-up employed.

Pacheo (61) conducted two experiments to determine the effects of warming-up upon jumping performance as measured by the Henry vertical jump testing apparatus. In the first experiment, one female and nine male graduate students were tested several times by performing six jumps with one and a half minutes of rest between each jump. The subjects followed a rotating order in performing these warm-up methods: 1) no warm-up, 2) three minutes of exercise to stretch the leg and hip muscles, 3) three minutes of stationary running at the subject's own pace, and 4) three minutes of deep knee bends done at a prescribed cadence. It was found that with only two minor exceptions, all subjects jumped significantly higher after all three of the warm-up methods than when no warm-up preceded the testing, the improvement after stationary

running being the most highly significant. In the second experiment, fifty male university students were tested on five jumps per period directly after deep knee bends and with no preliminary exercise. Once again, warming up was found to be statistically significant in improving jumping performance.

Pacheo (60) also investigated relationships between warming up and the jumping performance of 166 junior high school girls. The subjects took five trials of the jump and reach test on two separate days. On the first day half of them performed with no warm-up and the other half was tested approximately a minute and a half after completing a warm-up exercise of three minutes of vigorous running in place; on the second day the two groups reversed these preliminary procedures. It was concluded that preliminary warm-up exercises such as running in place result in a highly significant improvement in the vertical jumping performance of junior high school girls and that the warm-up effect of one trial upon the next consecutive trials is a negligible factor in this improvement.

Chavez, as cited by Hohman (73), studied the effects of warm-ups upon muscular performance as measured by the vertical jump, the grip dynamometer, and the time taken to pedal a bicycle ergometer 100 revolutions. Thirty adult male subjects performed these tests after either no warm-up, a seven minute warm-up, or a twenty-one minute warm-up period. An analysis of the results led to the following conclusions: 1) vertical jumping performance was highest after the twenty-one minute warm-up and lowest after no warm-up period, 2) there was no significant difference between the mean scores on the grip strength test in favor of

any of these three methods, and 3) no warm-up seemed to be most beneficial to performance on the bicycle ergometer.

Thompson (68) tested five groups of subjects in an attempt to determine the effects of various warm-ups upon the following aspects of physical performance: speed and endurance in swimming, accuracy in basketball foul shooting, accuracy in bowling, speed and accuracy in typing, and leg extensor strength.

In Part I, sixty college men were divided into groups of thirty-four sprint swimmers to be timed on 30-yard swims and twenty-six endurance swimmers tested on the number of laps swum in five minutes. After a four week conditioning program, a four week testing program was conducted in which the subjects performed six times after five minutes of rest, three times after a related swimming warm-up which was followed by five minutes of rest, and three times after an unrelated warm-up of calisthenics followed by five minutes of rest. It was found that sprint and endurance swimming performances were both significantly improved by the related warm-ups, while the other two methods had no significant influence upon performance.

In Part II of Thompson's study, twenty college men highly skilled in basketball were tested on their accuracy in twenty consecutive foul shots. Each subject was tested six times, alternating daily between no warm-up and a related warm-up which consisted of the following routine: ten minutes of general floor shooting, three minutes of passing, and shooting ten foul shots. Accuracy in foul shooting was found to be improved by the related warm-up, this finding being significant at better than the one per cent level of confidence.

Part III was concerned with the bowling scores of 56 adults skilled in this activity. Considering games bowled to be related warm-ups for successive games, it was found that this warm-up resulted in significantly higher bowling scores.

Nineteen college women participated in Part IV to evaluate the effects of warm-ups upon speed and accuracy in typing. Each subject was tested six times with no warm-up, three times after a related warm-up of typing a preparatory drill for three minutes, and three times after an unrelated warm-up of three minutes of finger calisthenics. It was found that neither accuracy nor speed in typing was improved by either of the warm-up methods.

In Part V, twenty male subjects enrolled in a college softball class were tested for leg extensor strength by means of a dynamometer. It was found that an unrelated warm-up of vigorous calisthenics resulted in no significant improvement over performance with no warm-up.

In concluding, Thompson noted that warm-up seems to benefit performance as measured by group averages but that there is a wide variability in the effect of warm-up upon individual performance and certain subjects within a group may not demonstrate an improvement in performance as a result of preliminary warming up.

Hohman (73) compared the relative merits of three experimental methods of warming up upon basketball shooting performance. Twenty-three college men of varying degrees of basketball playing ability were tested on their accuracy in twenty-four shots from twenty-four different locations on the basketball floor. Following a random order, the following procedures preceded testing: 1) no warm-up, 2) a seven

minute unrelated warm-up of vigorous exercises and sprint running, and 3) a related warm-up which included one minute of lay-ups, one minute of sprint dribbling, and five minutes of set shooting from various positions on the floor. Each subject was tested a total of nine times - three times after each warm-up method. From an analysis of data, there was found to be a highly significant improvement in shooting accuracy when the related warm-up preceded testing. In comparing the three methods, the mean score after the unrelated warm-up was lower, though not statistically so, than mean scores recorded after no warm-up. In discussing this finding, Hohman stated that the unrelated warm-up may have been so severe that fatigue influenced the results. The general conclusion drawn from this study was that motor performance can be improved by a related warm-up.

In summary, it is recognized that experimental evidence on relationships between warm-ups and physical performance is varied and somewhat confusing.

Asmussen and Boje, and Schmid reported that rides on the bicycle ergometer were improved by warming up. On the other hand, Chavez, Karpovich and Hale, and Skubic and Hodgkins found that warm-ups did not result in significantly improved performance on the bicycle ergometer.

Using varied measurements to discern the effects of unrelated warm-ups upon muscular strength, Burke, Buxton, Dohrmann, and Oliver found that performance was significantly improved; however, Chavez and Thompson observed no significant improvements in strength. Asmussen and Boje's results showed that strength was increased when warm-ups involved a rise in the temperature of the muscles being tested, but that

there was no improvement with warm-ups which did not raise the muscle temperature. Skubic and Hodgkins, using the softball throw for distance as a measure of strength, concluded that neither related nor unrelated warm-ups contributed significantly to improving performance; however, Michael, Skubic and Rochelle found that softball throws were significantly longer when preceded by either one of these warm-up methods. In assessing power, Oliver found that it was increased by an unrelated warm-up in the case of the standing broad jump but not in the softball throw for distance.

Burke, Lotter, Oliver, and Skubic and Hodgkins all found that speed of movement was not significantly improved with warm-ups; but Swegan, Yankosky and Williams concluded that speed of movement was enhanced by preliminary exercise.

Burke, and Skubic and Hodgkins concluded that accuracy was not favorably influenced by warming up, but Hohman's results indicate that accuracy is improved with a related warm-up. Thompson found accuracy in typing to be unaffected by either related or unrelated warm-ups, but his study also showed that accuracy in bowling and in basketball foul shooting was significantly improved by related warm-ups.

Burke's experimental results indicate that endurance is not increased by warming up, while Asmussen and Boje, and Thompson obtained results leading to the opposite conclusion that a warm-up does improve performance in activity requiring endurance.

Blank, Raines, Schmid; and Simonson, Telensko and Gorken found that a warm-up was beneficial to various kinds of running, while the results obtained by Hipple; Karpovich and Hale, Matthews and Snyder, and

Sills and O'Riley do not support the conclusion that a warm-up improves running performance. Kaufmann found that although a combination of warm-up and recovery techniques resulted in better running times than no activity at all, a standard warm-up alone did not result in a significant improvement in running.

In studies concerned with swimming, Muido reported that unrelated warm-ups improved performance, while DeVries and Thompson found no significant improvement with unrelated preliminary exercise. Schmid observed beneficial results from warming up and indicated that related warm-ups improved performance the most. DeVries and Thompson found swimming performances significantly improved only after related warm-ups.

Pacheo, in a series of three experiments, found that three different warm-up methods resulted in significantly higher vertical jumps than when no warm-up was performed; and Chavez's results confirm the conclusion that warming up is beneficial to physical performance in vertical jumping.

Only three studies which dealt with the effects of warming up upon basketball shooting performance could be found. Skubic and Hodgkins concluded that neither related nor unrelated warm-ups improved foul-shooting ability, but Thompson's results demonstrated a significant improvement in foul-shooting after a related warm-up. Hohman observed that an unrelated warm-up had no beneficial effect upon basketball shooting from various positions on the floor; whereas when this same performance was preceded by a related warm-up, significantly improved scores resulted.

It would seem, from this review of experimental studies, that relationships between warm-ups and physical performance represent a controversial topic, posing some questions which have yet to be conclusively answered. Many of the results cited are contradictory, and attempts to discern the effects of warming up upon performance are further confused by the many different warm-up methods and experimental designs employed.

There are two aspects of the warm-up question, however, which seem to be points of near common agreement - that warm-up effects differ with individuals, and that a related warm-up is preferable to an unrelated preliminary exercise. Raines; Swegan, Yankosky and Williams; and Thompson were among the writers who reported individual variations in the influence of warm-ups upon performance. Of the studies investigating the effects of related warm-ups upon physical performance, only that of Skubic and Hodgkins did not yield positive results. Contrary to this, Michael, Skubic and Rochelle found that a related warm-up resulted in significantly better performance than when no warm-up preceded testing; and DeVries, Hohman, Schmid, and Thompson all found that the best group performances in their experimental studies occurred after participation in related warm-ups. Suggestions in favor of performing related warm-ups instead of unrelated warm-ups are further strengthened by the discussions of Burke and of Karpovich and Hale, as well as those found in several books.

CHAPTER III

PROCEDURE

The purpose of this study was to determine and compare the relative effects of three different warm-up procedures upon physical performance as measured by three selected objective skill tests which were used to evaluate basketball playing ability. Each test was taken nine times by each subject - three times after no warm-up, three times after an unrelated warm-up, and three times after a related warm-up. The scores resulting with each warm-up method were then analyzed and compared.

Subjects

The subjects in this study were nineteen undergraduate students enrolled at the Woman's College of the University of North Carolina during the academic year 1959-60. Their selection for participation in the study was determined by their relatively high skill level in basketball. All of these college women were in good health and had been designated as outstanding players in an inter-dormitory basketball tournament which had been completed at the Woman's College of the University of North Carolina. On this basis, they had been selected as members of the extramural basketball team.

Selection of Tests

Most authorities on testing and evaluation in physical education state that it is difficult to measure total playing ability in basketball because of the inherent difference between game and testing

situations; however, they also state that there are several objective skill tests which give valid and reliable indications of motor ability in basketball. Dyer, Schurig and Apgar (41), in an analysis of motor skills important to successful performance in basketball, concluded that there are three fundamental and general skill areas - ball handling, basket shooting, and jumping. The tests selected for this study included measurement of these three fundamental basketball skills as well as some more general aspects of performance.

The following tests were used in this study: 1) Scott's Passing Test (Modification of Edgren's Ballhandling Test), 2) Half-Minute Shooting Test, and 3) Jump and Reach Test. Test descriptions may be found in the Appendix.

The passing test was chosen primarily to measure ball handling and, at the same time, was a measure of agility and speed.

The half-minute shooting test was selected mainly for the purpose of evaluating basketball shooting ability. In addition this test involves the ability to judge rebounds and the ability to move quickly to catch the ball and put it in play. (27, p. 80) After analyzing several basketball skill tests, Leilich concluded that the half-minute shooting test ". . . appears to be slightly superior to all other shooting tests in measuring shooting accuracy and speed." (76, p. 52)

The jump and reach test measures a skill which is basic to performance in many activities - the distance a person can vertically jump. This test is generally considered to be a good index of power.

While the half-minute shooting test seems to be more or less specific to basketball, it has been found that the other two tests show a

close relationship with general motor ability (76); thus the results of this study might be applicable to a broader area of physical performance than that of basketball alone.

Warm-ups

For purposes of this study it was necessary to define and distinguish between the methods of warm-up employed. An unrelated warm-up was defined as active preliminary exercise which is general in nature and results in activation of the body systems at a nonfatiguing level. A related warm-up is also active preliminary exercise which activates the body systems at a nonfatiguing level, but it differs from an unrelated warm-up in that it is specific to the activity that it precedes, involving movements which closely resemble those used in the actual test and thus requiring similar neuromuscular coordinations. No warm-up, in this study, simply meant the absence of activity just prior to test performance.

The nature, intensity, and duration of the active warm-ups used in this study were decided upon in light of their stated purposes and in relation to the physical capacities of the subjects. An attempt was made to have the warm-ups be vigorous enough to have at least some effect upon all of the subjects and yet not be too strenuous for any of them.

In all cases the unrelated warm-up consisted of running four laps around the gymnasium at the subject's own pace. This exercise was chosen because it is a natural activity which involves the whole body and is often performed in connection with warming up for various sports.

Physiologists seem to agree that there is no one optimum running pace, and therefore the subjects were allowed to regulate their own speeds according to their individual abilities. The subjects were told to begin trotting and gradually increase their pace of running, completing the four laps at the fastest rate which could be accomplished with moderate effort. In addition, each subject was encouraged not to let her pace be influenced by anyone else who might be running at the same time.

The related warm-ups varied according to the test activities and are fully described in the Appendix. Each included movements and skills similar to those required in the test performance and followed a progression from fairly light and general to more strenuous and specific activity. The related warm-ups for the passing and shooting tests involved use of a basketball and practice in handling it, while the related warm-up for the jump and reach test consisted of calisthenic exercises and some practice in jumping. The calisthenic routine which preceded the jump and reach test was composed of three exercises which are generally used to stretch various muscles and increase flexibility, and the final part of this warm-up consisted of quite vigorous activity which included practice in jumping and reaching as high as possible. In all three related warm-ups, as soon as one part was completed the next was begun. In cases where activities were performed for designated periods of time, a stop watch was used.

Experimental Design and Procedure

Prior to the testing program, twenty college women were contacted

individually to request their participation in the study. Of this number nineteen agreed to serve as subjects. Testing schedules were set up, and the subjects were requested to put forth their best efforts at all times. As a psychological control, the true purpose of the study was not revealed to the subjects, but rather they were told that this study was an attempt to determine the long term effects of a light training program upon physical performance. In order to keep the procedures followed in this study as close to normal as possible, the subjects were not required to follow any particular practices outside of or just previous to participation in the program.

All nineteen subjects participated in the whole nine week testing program which involved a total of twenty-seven testing days - nine with no warm-up, nine with an unrelated warm-up, and nine with a related warm-up. The total testing program was divided into three periods of three weeks, each of which involved just one test and was more or less complete in itself. The first test administered was the passing test, second was the half-minute shooting test, and finally the jump and reach test.

During a period of three consecutive weeks, each subject took the designated test a total of nine times - three times after each of the three different warm-up methods. The testing schedule was arranged so that any given subject took the test at approximately the same time of day on the same three days of the week throughout a three week testing period. In an attempt to rule out possible learning effects in favor of any one method, a systematic rotation of warm-up methods was followed. The order of warm-up procedures used for all three tests was as follows:

Day	Week I	Week II	Week III
1	No warm-up	Unrelated warm-up	Related warm-up
2	Unrelated warm-up	Related warm-up	No warm-up
3	Related warm-up	No warm-up	Unrelated warm-up

All tests were administered in Coleman Gymnasium at the Woman's College of the University of North Carolina in accordance with the test instructions stated in the Appendix. The same person administered all tests and, with very few exceptions, the same stop watch was used for all testing during a three week period.

When no warm-up was performed, the subjects took the test without any preliminary exercise or practice. On the days that unrelated or related warm-ups were performed, testing was begun almost immediately upon the completion of this activity; although, when working with partners, sometimes as long as thirty seconds elapsed between the warm-up and test performance.

For the passing test the subjects were divided into groups which came at separate times. Within each group the subjects worked in pairs so that while one partner performed, the other kept and then recorded the score. Partners alternated in being tested and keeping score until all had taken the three trials for that test. Scores were then handed in and officially recorded.

In the half-minute shooting test, only two subjects could be scheduled at a time due to the fact that only two baskets were available and each subject needed a basket to herself for the related warm-up. Subjects alternately performed trials, and shot at the same basket throughout the three week testing period. All scores for this test were counted and recorded by the tester.

Two or three subjects performed simultaneously in the jump and reach test. Strips of brown paper were marked off in inches and taped at appropriate heights on the wall of the gymnasium so that chalk marks could be easily discerned and scores readily recorded by the tester.

Controls

Attempts to control several variables which might affect test results included the following:

1. Skilled basketball players were used as subjects in order to ensure some consistency in performance.
2. The real purposes of the study were not stated and thus the possibility of performance being influenced by prejudices in favor of any of the warm-up methods was reduced.
3. At the beginning of the study the subjects were strongly urged to put forth their best efforts at all times.
4. The order of warm-ups was rotated to balance out possible learning effects.
5. Insofar as possible, the tests were administered under exactly the same conditions throughout each three week testing period.

Treatment of Data

The raw scores were first used in analyses of variance which were undertaken for each of the skill tests in order to test the null hypothesis that there was no significant difference in performance scores due to any of the warm-up procedures which preceded testing. The factorial design was used in the analyses of variance so that the influence of the variables - warm-ups, weeks, and individuals - could be studied in all possible combinations. Sums of squares were calculated and then divided by the appropriate number of degrees of freedom in order to determine the mean square for each of the main sources of variation as

well as their interactions. By dividing this mean square between groups by the calculated mean square within groups, the value of F was found and this provided a basis for determining whether or not there were significant differences in performance due to the warm-up methods. If the F ratio for the variation between warm-ups was found to be significant at the 5% level of confidence or better, further investigation of the difference between methods was justified.

The method used to further test the null hypothesis that there was no significance in performance scores due to any of the warm-up procedures was Fisher's t test for significance of difference. Means were computed for the totals of nineteen scores which were recorded at each testing session, and the differences between the mean scores for each warm-up method during each week of testing could then be compared and tested for significance. The difference in means was divided by the standard error in order to find the value of t. Values of t which were required for rejection of the null hypothesis at the 5% and 1% levels of confidence were 2.093 and 2.861 respectively. Finally, in each test, one mean score for each of the warm-up methods was obtained by averaging the three separate mean scores which had previously been computed. By applying Fisher's t test for significance of difference to these means, it was possible to determine the relative effects of the experimental warm-up methods upon performance in each test as a whole.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

Presentation and Analysis

The purpose of this experiment was to determine the relative effects of three selected warm-up methods upon physical performance as measured by three objective basketball skill tests. From the nine scores which were recorded for each of the nineteen subjects for each test, performances after each of the experimental warm-up procedures were analyzed and compared.

Analysis of Variance in the Passing Test

A summary of findings from a factorial analysis of variance which was applied to the passing test can be found in Table I. In this analysis it was found that there was a difference between warm-up methods which was significant at the 1% level of confidence. Differences in scores from week to week and from individual to individual were also significant at the 1% level. The warm-up x weeks interaction and the weeks x individuals interaction showed significance at the 1% and 5% levels respectively, while the warm-ups x individuals interaction was not statistically significant.

Analysis of Variance in the Half-Minute Shooting Test

A summary of the findings from an analysis of variance of scores collected in the half-minute shooting test can be found in Table II, page 44. The variation between warm-ups was significant at the 1% level of confidence. Differences between weeks and between individuals were

TABLE I

SUMMARY OF ANALYSIS OF VARIANCE
IN THE PASSING TEST

Source of Variation	Sum of Squares	df	Mean Square	F
Warm-ups	709.48	2	354.74	79.53**
Weeks	1,337.55	2	668.78	149.96**
Individuals	1,170.55	18	65.03	14.58**
Interaction: warm-ups x weeks	283.40	4	70.85	15.88**
Interaction: warm-ups x individuals	192.96	36	5.36	1.20
Interaction: weeks x individuals	303.56	36	8.43	1.89*
Replication (Within Groups)	320.83	72	4.46	
Total	4,318.33	170		

* Significant at 5% level of confidence

** Significant at 1% level of confidence

TABLE II

SUMMARY OF ANALYSIS OF VARIANCE
IN THE HALF-MINUTE SHOOTING TEST

Source of Variation	Sum of Squares	df	Mean Square	F
Warm-ups	219.27	2	109.64	57.10**
Weeks	68.22	2	34.11	17.77**
Individuals	547.09	18	30.39	15.83**
Interaction: warm-ups x weeks	16.80	4	4.20	2.18
Interaction: warm-ups x individuals	96.95	36	2.69	1.40
Interaction: weeks x individuals	119.33	36	3.31	1.72*
Replication (Within Groups)	138.32	72	1.92	
Total	1,205.98	170		

* Significant at the 5% level of confidence

** Significant at the 1% level of confidence

also found to be significant at the 1% level of confidence. The weeks x individuals interaction was significant at the 5% level of confidence, while the other two interactions (warm-ups x weeks and warm-ups x individuals) did not show significance at an acceptable level.

Analysis of Variance in the Jump and Reach Test

A summary of the results from this analysis of variance can be found in Table III. Once again all three of the main sources of variation - warm-ups, weeks and individuals - showed significance at the 1% level of confidence. The interactions warm-ups x weeks and weeks x individuals were significant at the 5% and 1% levels of confidence respectively, while the warm-ups x individuals interaction was not statistically significant.

Summary of Findings in the Analyses of Variance

Combining information from the three separate analyses of variance, it is seen that in all three skill tests the variations between warm-ups, between weeks, and between individuals were significant at the 1% level of confidence. The warm-ups x weeks interaction was significant at the 1% level in the passing test and the 5% level in the jump and reach test, but was not statistically significant in the half-minute shooting test. The weeks x individuals interaction was found to be significant in all three tests, this difference reaching significance at the 1% level of confidence in the jump and reach test and the 5% level in the passing and half-minute shooting tests. In none of the tests was a significant variation found in the warm-ups x individuals interaction.

TABLE III

SUMMARY OF ANALYSIS OF VARIANCE
IN THE JUMP AND REACH TEST

Source of Variation	Sum of Squares	df	Mean Square	F
Warm-ups	432.43	2	216.22	30.73**
Weeks	371.55	2	185.78	27.69**
Individuals	15,260.52	18	847.80	126.34**
Interaction: warm-ups x weeks	72.78	4	18.19	2.71*
Interaction: warm-ups x individuals	375.08	36	10.41	1.55
Interaction: weeks x individuals	1,543.46	36	42.87	6.71**
Replication (Within Groups)	483.54	72	6.71	
Total	18,539.36	170		

* Significant at the 5% level of confidence

** Significant at the 1% level of confidence

Significance of Differences Between Warm-Up Methods During Each Week

A summary of findings from application of Fisher's t test for significance of difference between the mean scores for the warm-up methods during each week can be found in Table IV.

In the first week of the passing test, both the unrelated and related warm-ups resulted in significantly higher scores than when no warm-up preceded test performance. In addition, it was found that the related warm-up resulted in significantly better performance than the unrelated warm-up. All three of these differences were significant at the 1% level of confidence.

In the second week of the passing test it was found that no warm-up resulted in slightly better performance than the unrelated warm-up, but this difference was not statistically significant. The related warm-up was superior to both of the other methods, the differences in favor of this method being significant at the 1% level of confidence in both cases.

The third week of testing produced differences which were significant at the 1% level of confidence in favor of both the unrelated and related warm-ups over no warm-up. The related warm-up resulted in slightly higher scores than the unrelated warm-up, but this difference was not a statistically significant one.

Results from the passing test showed that in two out of three cases the unrelated warm-up resulted in significantly higher mean scores than no warm-up. The related warm-up resulted in better performance than no warm-up in all three comparisons and was superior to the unrelated warm-up in two out of three cases. All differences found

TABLE IV

SIGNIFICANCE OF DIFFERENCE BETWEEN WARM-UP METHODS
BASED UPON SEPARATE MEAN SCORES FOR EACH DAY'S PERFORMANCE

N = 19

Situation	Difference Between Means	t	Level of Significance
Passing Test			
Week I			
U-N	4.95	7.17	1%
R-N	8.63	12.51	1%
R-U	3.68	5.33	1%
Week II			
N-U	.94	1.36	
R-N	2.94	4.26	1%
R-U	3.88	5.62	1%
Week III			
U-N	2.78	4.03	1%
R-N	3.36	4.87	1%
R-U	.58	.84	
Half-Minute Shooting			
Week I			
U-N	1.47	3.27	1%
R-N	3.32	7.38	1%
R-U	1.85	4.11	1%
Week II			
U-N	1.16	2.58	5%
R-N	2.95	6.55	1%
R-U	1.79	3.98	1%
Week III			
U-N	1.79	3.98	1%
R-N	2.06	4.58	1%
R-U	.27	.60	
Jump and Reach			
Week I			
U-N	3.09	3.68	1%
R-N	4.55	5.42	1%
R-U	1.46	1.73	
Week II			
U-N	1.31	1.56	
R-N	3.94	4.69	1%
R-U	2.63	3.13	1%

TABLE IV (Continued)

Situation	Difference Between Means	t	Level of Significance
Jump and Reach (Continued)			
Week III			
U-N	3.77	4.49	1%
R-N	2.81	3.34	1%
U-R	.96	1.14	

N- No warm-up
U- Unrelated warm-up
R- Related warm-up

between means in the passing test were significant at the 1% level of confidence.

In the first week of the half-minute shooting test it was found that both the unrelated and related warm-ups resulted in significantly higher mean scores than no warm-up, with the related warm-up being significantly superior to the unrelated warm-up. All three of these differences were significant at the 1% level of confidence.

The second week of testing produced the same pattern as that noted in the first week, the only difference being that the unrelated warm-up resulted in significantly higher scores than no warm-up at the 5% level of confidence where this difference had been at the 1% level in the first week.

In the third week of the half-minute shooting test, significant differences were found at the 1% level of confidence in favor of both the unrelated and related warm-ups over no warm-up. The related warm-up resulted in a very slightly higher mean score than the unrelated warm-up, but this difference was statistically insignificant.

Results from this shooting test showed that, in all comparisons, both the unrelated and related warm-ups produced significantly higher performance scores than when no warm-up preceded testing. In two out of the three cases where the unrelated and related warm-ups were compared, the related warm-up proved to be significantly superior to the unrelated warm-up.

In the first week of the jump and reach test, both the unrelated and related warm-ups resulted in significantly higher mean scores than no warm-up, these differences being significant at the 1% level of con-

fidence. The related warm-up produced slightly higher scores than the unrelated warm-up, but there was no significant difference between these two active warm-up methods.

The second week of testing showed that the related warm-up resulted in significantly better jumping performances than either the unrelated warm-up or no warm-up. Both of these differences were significant at the 1% level of confidence. The unrelated warm-up produced a slightly higher mean score than no warm-up, but this difference was not statistically significant.

The third week of the jump and reach test showed differences in favor of both the unrelated and related warm-ups over no warm-up, these being significant at the 1% level of confidence. The unrelated warm-up resulted in a very slightly higher mean score than the related warm-up, but this difference was statistically insignificant.

The jump and reach test demonstrated significant differences in favor of the unrelated warm-up over no warm-up in two out of three cases and a favorable influence of the related warm-up over no warm-up in all three comparisons. The two active warm-ups differed significantly in only one case, this being in favor of the related warm-up over the unrelated warm-up. All significant differences found in this test reached the 1% level of confidence.

Significance of Difference Between Warm-up Methods Based Upon a Single Mean Score for Each Method in Each Test

A summary of findings from application of Fisher's t test for significance of difference between the single mean score for each warm-up method in each test can be found in Table V.

TABLE V

SIGNIFICANCE OF DIFFERENCE BETWEEN WARM-UP METHODS
BASED UPON A SINGLE MEAN SCORE FOR EACH METHOD IN EACH TEST

Situation	Difference Between Means	t	Level of Significance
Passing Test			
U-N	2.27	3.29	1%
R-N	4.98	7.22	1%
R-U	2.71	3.93	1%
Half-Minute Shooting			
U-N	1.47	3.27	1%
R-N	2.77	6.15	1%
R-U	1.30	2.88	1%
Jump and Reach			
U-N	2.73	3.25	1%
R-N	3.77	4.49	1%
R-U	1.04	1.24	

N- No warm-up
U- Unrelated warm-up
R- Related warm-up

On the basis of comparisons made between the over-all mean scores for each warm-up method in the passing test, it was found that both the unrelated and related warm-ups resulted in significantly better performances than when no warm-up preceded testing. In addition, the mean score occurring with the related warm-up was significantly higher than that with the unrelated warm-up. All three of these differences were significant at the 1% level of confidence.

The mean scores based on three administrations of the half-minute shooting test with each warm-up method showed the same pattern as that found in the passing test. Both the unrelated and related warm-ups resulted in better performances than no warm-up, while the related warm-up was superior to the unrelated warm-up. Once again, all three of these comparisons showed differences which were significant at the 1% level of confidence.

In the jump and reach test it was found that both the unrelated and related warm-ups resulted in better performances than no warm-up, these mean differences being significant at the 1% level of confidence. The related warm-up resulted in a slightly higher mean score than the unrelated warm-up, but this difference was statistically insignificant.

Interpretation of Data

Analyses of Variance

In the analyses of variance, it was anticipated that there would be significant variations between individuals and between weeks. Although the subjects were all highly skilled, it was expected that their performance levels would show some differences. Weekly variations in

performance were expected because of the practice involved in the testing program. The factorial design was used so that the influence of these anticipated variations could be taken into account in determining the relative effects of the experimental warm-up methods.

An analysis of variance in the passing test showed that there was a highly significant difference between the warm-up methods, thus indicating that resulting performances were definitely influenced in some way by these experimental procedures. Since the warm-ups x weeks interaction was significant while the warm-ups x individuals interaction was statistically insignificant, this test indicates that the warm-up methods were significantly different in their effects from week to week but that their influence upon different individuals did not significantly vary. As was expected, there were highly significant differences between performance levels from individual to individual and from week to week.

An analysis of variance in the half-minute shooting test showed a highly significant difference between the warm-ups and their effects upon performance. In addition, it was found that results were not significantly affected by the interactions of warm-ups x weeks or warm-ups x individuals, thus indicating a consistent influence of the experimental warm-up methods from individual to individual and from week to week. Individual and weekly performance levels differed very significantly, and there were variations between individuals in their performances from week to week.

An analysis of variance in the jump and reach test showed a highly significant difference in scores resulting after the different warm-up methods. It was also found that the warm-ups x individuals interaction

was not significant, thus indicating that the warm-up effects were similar in the subjects individually and as a group. In addition, the warm-up x weeks interaction was significant, indicating that the effects of the three warm-up methods varied from week to week. Once again, as was expected, scores differed very significantly both from week to week and from individual to individual.

From these three separate analyses of variance it was found that performance scores in all three tests were significantly influenced by the experimental warm-up methods which preceded testing; however, no information was provided concerning which method or methods were resulting in better performances. The results of the analyses of variance thus led to application of Fisher's t test for significance of difference in order to determine where and how significant these differences were.

Significance of Differences Between Warm-up Methods

From the outcome of applying Fisher's t test for significance of difference between mean scores for each separate performance in the passing test, it was seen that the related warm-up consistently resulted in better performance scores than when no warm-up preceded testing. The unrelated warm-up resulted in better performances than no warm-up in two out of three comparisons and, similarly, the related warm-up was superior to the unrelated warm-up in two out of three cases. By combining the three separate means into one mean score for each method, it was found that both the unrelated and related warm-ups resulted in better performances than no warm-up and that the related warm-up produced better performances than the unrelated warm-up. Since all mean differences in

the passing test were significant at the 1% level of confidence, it appears that in this type of performance an unrelated warm-up is better than no warm-up and a related warm-up is better than an unrelated warm-up.

Since the passing test was primarily a measure of ball handling, the results of this test are not directly comparable to those obtained in any of the experimental studies reviewed. However, since this test also measured speed and agility, it might be somewhat comparable to the part of Oliver's study in which the zigzag run was administered to junior high school boys as a test of speed and agility. In making this comparison, the results of this study are contrary to Oliver's finding that an unrelated warm-up did not improve performance in an activity measuring speed and agility.

The tests of significance of difference between mean scores in the half-minute shooting test during each week showed that in all comparisons both the unrelated and related warm-ups resulted in significantly better performances than when no warm-up was performed. In two out of three cases, the related warm-up produced significantly higher scores than the unrelated warm-up. In combining the three separate mean scores into one for each warm-up method, it was found that there were highly significant differences in favor of both the unrelated and related warm-ups over no warm-up. In addition, the related warm-up was found to be significantly superior to the unrelated warm-up. From these findings, it seems that performance in basketball shooting is better after an unrelated warm-up than after no warm-up and that a related warm-up results in better performance than either of the other warm-up

methods used in this study.

The results from the half-minute shooting test are comparable to three other studies which measured basketball shooting ability. The findings of this study were directly opposed to those of Skubic and Hodgkins in which neither an unrelated nor a related warm-up resulted in significantly improved foul shooting scores for college women. It might be noted, however, that although the purposes of the two studies being compared were very similar, the warm-up methods used were quite different as Skubic and Hodgkins' light warm-ups consisted of twelve jumping jacks for an unrelated preliminary exercise and three practice free throws for the related activity, both of these warm-ups being followed by five minutes of rest before performance in the test. Thompson's study of the effects of a related warm-up upon shooting performance was more closely comparable to this experiment since the warm-up was quite similar to that used in this study. The results of this study are in agreement with Thompson's finding that a related warm-up produced significantly better performances than when no warm-up preceded testing. The findings of this study are partially in agreement with those of Hohman and partially contrary to them. In this study it was found that an unrelated warm-up resulted in significantly higher performance scores than no warm-up, while Hohman found no significant difference between these two methods. However, the results of this study are in accord with Hohman's finding that a related warm-up produced significantly higher mean scores than either no warm-up or an unrelated warm-up.

In analyzing each week of the jump and reach test, it was found that the unrelated warm-up resulted in better performances than no

warm-up in two out of three comparisons and the related warm-up consistently produced better scores than no warm-up. In only one case was a significant difference found between the active warm-up methods, and this was in favor of the related over the unrelated warm-up. Using the single mean score for each warm-up method, it was found that both the unrelated and related warm-ups resulted in better performances than no warm-up and that there was no significant difference between the two active warm-ups. These results indicate, once again, that both the unrelated and related warm-ups produced significantly better performances than no warm-up. With some reservations, since this occurred in only one out of three comparisons, it might be suggested that the related warm-up tends to be superior to the unrelated warm-up in its effects upon jumping performance.

The finding that an unrelated warm-up results in significantly better jumping performances than no warm-up is in agreement with the similar studies of Pacheo and of Chavez who found these same differences. The effect of the related warm-up can not be directly compared since the other studies did not involve practice in jumping, but it can be noted that Pacheo reported significant improvements in vertical jumping performance when testing was preceded by calisthenic exercises similar to those performed as part of the related warm-up in this study. Since the jump and reach test is often considered an index of power, the results of this study might be compared to Oliver's findings concerning the effects of an unrelated warm-up upon performances measuring power. This study concurs with Oliver's finding that power was improved by an unrelated warm-up in the case of the standing broad jump, but is contrary

to his finding that power, as measured by the softball throw for distance, was not increased.

In attempting to interpret the data obtained from these three tests all together, it seems that the same general trends were common to each. These findings lead to the conclusion that, in the tests of physical performance used in this experiment, the warm-up methods resulted in significantly different scores. Further, it appears that physical performances of this nature are better after an unrelated warm-up than when no warm-up precedes testing, and that a related warm-up results in significantly better performances than either of the other methods used in this study.

The finding that an unrelated warm-up results in significantly better physical performances than no warm-up is in agreement with the general conclusions of Asmussen and Boje; Blank; Buxton; Dohrmann; Michael, Skubic and Rochelle; Muido; Pacheo; Raines; Schmid; and Simonson, Telensko and Gorkin, while it is contradictory to the studies of DeVries; Hipple; Hohman; Karpovich and Hale; Kaufmann; Lotter; Matthews and Snyder; and Sills and O'Riley. The finding that an unrelated warm-up results in better performance than no warm-up is in partial agreement with the results of Burke, Chavez, Oliver, and Thompson who all found some performances improved and some unaffected by unrelated warm-ups.

The finding that a related warm-up results in significantly better performances than no warm-up agrees with the studies of DeVries; Hohman; Schmid; Swegan, Yanskosky and Williams; Thompson; and Michael, Skubic and Rochelle, but is contrary to that of Skubic and Hodgkins.

The idea that a related warm-up represents the most effective warm-up method agrees with the results of DeVries; Hohman; Schmid; and Thompson, but is contrary to the findings of Skubic and Hodgkins and of Michael, Skubic and Rochelle.

CHAPTER V

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 three selected objective basketball skill tests. The tests of performance were the following: 1) Scott's passing test, 2) Jones' half-minute shooting test, and 3) the jump and reach test. Each test was taken a total of nine times by nineteen college women of relatively 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 nonfatiguing level, and 3) a related warm-up which involved movements and skills similar to those in the test activity. Test performances immediately followed the completion of the preliminary exercises, and a systematic rotation in order was followed in order 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.

A factorial analysis of variance for each test showed that there were significant differences between warm-up methods in all three tests. Further investigation by t tests for significance of difference between mean scores with each method gave the following results:

1. In the passing test, the related warm-up consistently resulted in better performance scores than when no warm-up preceded testing. The unrelated warm-up resulted in significantly better

performances than no warm-up in two out of three comparisons, and the related warm-up proved to be significantly superior to the unrelated warm-up in two out of three cases.

2. In the half-minute shooting test, it was found that in all comparisons both the unrelated and related warm-ups resulted in significantly higher performance scores than when no warm-up was executed. In two out of three cases, the related warm-up produced significantly better performances than the unrelated warm-up.

3. In the jump and reach test, the related warm-up consistently resulted in better performances than no warm-up. In two out of three cases it was found that the unrelated warm-up resulted in significantly higher scores than no warm-up. There was only one significant difference found from the three comparisons of the active warm-ups, and this was in favor of the related over the unrelated warm-up.

4. In studying the relative effects of the experimental warm-up methods upon performance in each test as a whole, it was found that in all three tests both the unrelated and related warm-ups resulted in significantly better performances than no warm-up. It was also found that the related warm-ups resulted in significantly higher mean scores than the unrelated warm-up in both the passing and half-minute shooting tests. In the jump and reach test it was found that performances were slightly better after the related warm-up than after the unrelated warm-up, but this difference was not statistically significant.

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 in this study, the general conclusion that physical performance in selected basketball skills is improved by active warm-ups seems justified. It can further be concluded that a related warm-up produces significantly better performances than an unrelated warm-up.

Implications of these conclusions for practical procedures in physical education would seem to be the following: 1) that it is worthwhile to execute preliminary exercises just prior to participation in basketball because performances will be better than if no warm-up precedes this activity, and 2) that best performances will occur when the warm-up is related to the skills used in basketball. Since two of the tests used in this study show a close relationship with general motor ability, it can further be suggested that warming up might improve performance in other activities and that optimum performance can be expected if the warm-up is specific to the activity it precedes.

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APPENDIX

DESCRIPTION OF WARM-UPS*

No Warm-up

The subjects dressed for activity upon their arrival at the gymnasium. Participation in the test was preceded by no prescribed procedure of rest or activity.

Unrelated Warm-up

In all cases the unrelated warm-up consisted of running around the gymnasium four times. Each subject was instructed as follows:

a) to run at her own pace

b) to begin running slowly, gradually and progressively increasing the pace

c) to complete the four laps as rapidly as she was able to with moderate effort.

Related Warm-ups

Subjects were encouraged to put forth enough effort so that they pushed themselves a little bit and yet were not tired out in completing the procedures described below.

Related Warm-up for the Passing Test

a) five minutes general floor shooting and rebounding

b) two minutes passing to a partner at a comfortable distance and pace

c) one minute wall passing as rapidly as possible from a distance of three feet.

Related Warm-up for the Half Minute Shooting Test

a) five minutes general floor shooting and rebounding

b) thirty seconds wall passing as rapidly as possible from a distance of three feet

c) one minute shooting from a position close to the basket.

Related Warm-up for Jump and Reach Test

Exercise I

Starting position: Standing erect with feet about twelve inches apart, hands on hips.

Count 1: Keeping knees straight, bend forward at the waist and touch left toe with right hand.

Count 2: Return to starting position.

Count 3: Repeat count 1 to opposite side, touching right toe with left hand.

Count 4: Return to starting position.

Repeat whole procedure four times.

Exercise II

Starting position: Standing erect with feet about eighteen inches apart, hands at sides.

Counts 1 & 2: Stretch the arms out sideways at shoulder level and bend the trunk downward as far as possible while keeping the knees straight. Hold the head up so it is in line with the spine and keep the upper back straight. One bounce forward for each count.

Counts 3 & 4: Return to upright position, placing left hand on left hip and right arm in a curved position overhead. Laterally bend the trunk to the left as far as possible, keeping the knees straight and letting the head and right arm hang downward to the left. One bounce to the left with each count.

Counts 5 & 6: Return to upright position, reverse the position of the arms and hands, repeat side bending (as described in counts 3 & 4) to the right side. One bounce right with each count.

Repeat the whole procedure four times.

Exercise III

Starting position: Standing erect with feet together, hands on hips.

Count 1: Keeping knees straight, bend forward and reach down with both hands to touch toes.

Count 2: Simultaneously assume squatting position and extend both arms forward at shoulder height with palms down.

Count 3: Simultaneously straighten knees and touch toes.

Count 4: Return to starting position.

Repeat whole procedure nine times.

Exercise IV

Trot from one side of the free throw lane to the other, pausing near the middle of it to jump as high as possible and reach toward the basketball net with the right hand. Repeat the same procedure, trotting back across the free throw lane and reaching as high as possible with the left hand.

Continue trotting back and forth, reaching with alternate hands, until a total of ten jumps has been completed.

* Preceding the selection of warm-ups, a small group of women physical education majors participated in several different warm-up exercises which had been designed for possible use in this study. From subjective comments of the students and empirical judgments of the writer, warm-ups which seemed to be of appropriate nature, intensity, and duration for the purposes of this study were selected.

DESCRIPTION OF TESTS

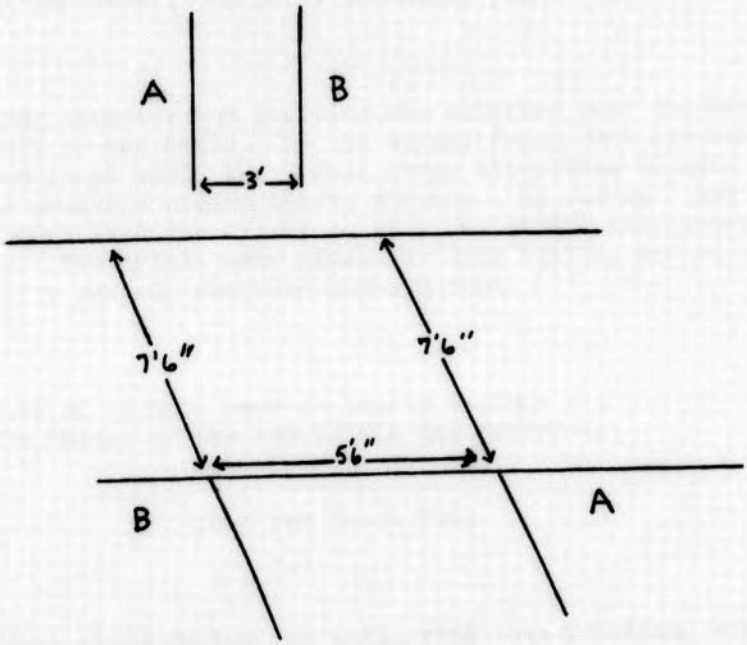
Passing Test (27, pp. 80-81)

Equipment:

1. A flat, unobstructed wall space. Official basketball, properly inflated. Stop watch.

2. Floor and wall markings as described and diagrammed below.

A line on the floor parallel to the wall and $7\frac{1}{2}$ feet from it. Two parallel lines on the wall three feet apart (width of lines included) in the center of the wall space. Lines on the floor fifteen inches to the outside of each line on the wall which intersect the original $7\frac{1}{2}$ foot restraining line. ($5\frac{1}{2}$ feet apart, lines included).



Test:

The subject stood in area A with a basketball in her hands. On the signal Ready, Go! she threw the ball to area A on the wall, ran forward to corner B or beyond so that she caught the ball on the rebound. She repeated from B, throwing to B on the wall and continued as rapidly

as possible until the signal to stop was given. Rules governing performance were the following: subjects had to stay behind the $7\frac{1}{2}$ foot restraining line at all times and throws had to be made while behind the proper parallel line, any type of pass could be used but the ball had to hit the wall on the correct side of the three foot zone to count, any type of turn or pivot was permissible and there was no penalty for traveling, the ball could bounce on the floor one or more times before being caught. Three trials of twenty seconds were given.

Scoring:

The score on each trial was the number of legal passes which hit the proper wall area (without line violations in the recovery) during the twenty seconds allowed. Scores for the three trials were added.

Half-Minute Shooting Test (27, p. 79)

Equipment:

Official basketball, properly inflated. Stop watch.

Test:

The player stood at any position she selected near the basket, with a basketball in her hands. On the signal Ready, Go! she started shooting and continued until the signal stop, attempting to make as many baskets as possible within thirty seconds. If the ball had left the subject's hands when the signal to stop was given, the basket counted if made. Two trials were given for each testing period, with an interval of thirty seconds elapsing between them.

Scoring:

The number of baskets made in thirty seconds was the score for each trial. The better of the two trials was recorded.

Jump and Reach Test

Procedure:

The subject stood facing the wall, with toes touching, both hands raised overhead. Reaching evenly with both hands, she marked the height of the reach with a piece of chalk held between the thumb and index finger. She then turned her preferred side to the wall and jumped, making a chalk mark as far up the wall as possible. Five vertical jumps were performed with a rest of thirty seconds allowed between trials.

Scoring:

The score for each trial was the difference between the reach while standing and jumping and was recorded to the nearest quarter of an inch. The test score was the total of the five trials.

RAW DATA

Half-Minute Shooting Test

S	WEEK I			WEEK II			WEEK III		
	N	U	R	U	R	N	R	N	U
1.	15	16	16	16	19	17	16	15	17
2.	11	11	13	14	16	15	18	14	16
3.	10	13	15	11	16	8	13	8	13
4.	7	9	15	15	16	11	15	11	17
5.	17	17	19	18	18	18	19	17	19
6.	16	15	17	17	16	15	15	13	16
7.	15	17	19	17	16	15	16	15	16
8.	14	10	15	12	17	14	16	16	16
9.	11	14	14	16	17	15	15	16	15
10.	12	14	17	15	15	15	18	11	14
11.	13	13	16	16	13	15	17	15	16
12.	12	13	12	12	14	12	17	14	16
13.	10	10	12	9	13	7	14	9	11
14.	11	14	18	16	17	13	15	16	16
15.	9	11	11	13	12	8	13	12	13
16.	12	14	15	13	19	13	18	16	16
17.	10	15	16	14	19	14	17	16	16
18.	9	13	13	13	17	12	13	14	17
19.	14	17	18	16	17	14	17	15	17

S- Subject
N- No warm-up
U- Unrelated warm-up
R- Related warm-up

RAW DATA

Passing Test

S	WEEK I			WEEK II			WEEK III		
	N	U	R	U	R	N	R	N	U
1.	25	32	36	37	43	35	42	38	40
2.	32	35	36	35	40	37	39	39	41
3.	29	37	38	39	42	35	42	39	40
4.	29	34	38	38	39	38	41	35	35
5.	37	36	43	41	45	42	46	45	46
6.	32	40	43	46	48	48	47	47	50
7.	30	35	40	37	40	40	44	38	40
8.	29	35	34	36	40	41	37	39	43
9.	28	29	33	35	40	38	41	37	44
10.	27	38	43	41	43	40	48	34	43
11.	28	31	36	36	39	36	41	39	43
12.	27	29	33	32	39	38	39	34	36
13.	31	35	39	38	41	35	34	37	35
14.	25	31	37	36	40	40	38	38	41
15.	25	32	37	37	45	39	41	36	42
16.	25	35	37	36	47	40	44	39	42
17.	33	38	42	38	39	42	43	37	43
18.	27	32	35	36	38	34	40	35	35
19.	32	31	35	36	36	30	35	32	32

S- Subject
N- No warm-up
U- Unrelated warm-up
R- Related warm-up

RAW DATA

Jump and Reach Test

S	WEEK I			WEEK II			WEEK III		
	N	U	R	U	R	N	R	N	U
1.	69	74	80¼	85½	93	89½	94½	87	96
2.	94½	100	92½	98	96½	94½	101	98½	94½
3.	79½	82	87½	84	89½	86½	95½	97	98
4.	62	64½	60	58	54	59	57-3/4	57½	58-3/4
5.	81	91½	95	93	90½	87	100½	102¼	97½
6.	72	70½	68	65½	69	60½	73-3/4	75¼	76½
7.	78	78½	86½	78-3/4	81¼	85-3/4	79-3/4	79½	88¼
8.	70½	72	82½	76½	80	71½	79	75½	78½
9.	81	87	84	83	83	82-3/4	81	74	81¼
10.	82½	96	94½	96½	100½	93-3/4	94-3/4	87-3/4	94½
11.	66½	71	67	72	71	70¼	73	68½	76-3/4
12.	90½	95	91	91½	93½	93½	96¼	99	103
13.	71	77½	79½	80	80½	76½	78½	73	73½
14.	90½	89	90½	87½	96½	89	89½	88½	90½
15.	87	90	89½	90	90½	80½	90¼	89½	87
16.	72	64½	75	75½	86	77½	82¼	72	82
17.	77-3/4	75	81½	81½	81	81-3/4	82½	76½	87½
18.	71½	76	81½	81½	87	79	79½	76	82
19.	83½	85	80½	81½	86½	76	79½	78	81

S- Subject
N- No warm-up
U- Unrelated warm-up
R- Related warm-up